The Thesis Committee for Yoganand Mandali
Certifies that this is the approved version of the following thesis:

Applications of microsimulation traffic data in infrastructure construction projects using 3D/4D CAD models

APPROVED BY
SUPERVISING COMMITTEE:

Supervisor: ______________________________
William J.O'Brien

____
Randy B.Machemehl

Applications of microsimulation traffic data in infrastructure construction projects using 3D/4D CAD models

by

Yoganand Mandali, B.Tech

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Abstract

Applications of microsimulation traffic data in infrastructure construction projects using 3D/4D CAD models

Yoganand Mandali, M.S.E

The University of Texas at Austin, 2013

Supervisor: William J.O'Brien

Transportation projects often involve communication of project information between diverse parties and have been a challenge with increasing complexity. Communication, review and feedback are very important for planners, builders/developers and traffic engineers for successful project execution. Past research was successful in finding effective ways to communicate to stakeholders and improve project performance. 3D/4D CAD modeling has been one among them which offers potential benefits from planning to construction phase owing to its wide range of capabilities. However, there is no single tool to analyze traffic conditions and changing geometry during construction for reviewing and better decision-making. A methodology to use DTA models as a source for traffic information and development of traffic visualization during construction with microsimulation output is discussed in this thesis. The benefits of adding traffic information to 3D/4D CAD models and some potential areas of application are explored. Two case studies on TxDOT transportation

construction projects are considered to explain the modeling and analysis for better understanding of different phases of the projects. Also, a small construction scenario was analyzed to validate the traffic data generated from DTA models for their use as an input to microsimulation models.

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List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
CAD	Computer Aided Design
DOT	Department of Transportation
DTA	Dynamic Traffic Assignment
FHWA	Federal Highway Administration
HCM	Highway Capacity Manual
ITS	Intelligent Transportation System
MUTCD	Manual of Uniform Traffic Control Devices
NTE	North Tarrant Express
PS&E	Plans Specifications and Engineering
PI	Public Information
ROW	Right of Way
TCP	Traffic Control Plan or Traffic Control Planning
TMP	Traffic Management Plan or Traffic Management Planning
TxDOT	Texas Department of Transportation
VPD	Vehicles Per Day

Chapter 1 Introduction

The thesis aims at assessing the applications of 3-Dimensional and 4-Dimensional Computer Aided Design (CAD) models combined with traffic data in different phases of transportation infrastructure construction projects by addressing planning, review and communication of proposed project plans.

Transportation projects involve construction activities taken up hand-in-hand with moving traffic on most of the projects. Effective maintenance of traffic is essential to ensure safety in construction work sites and mobility of the road users. Efficient co-ordination among transportation planners, design engineers, Traffic Management Planning (TMP) personnel and construction crew is necessary to accomplish these objectives.

Construction of highway projects involve high level of geometric complexity; traffic planning that gets changed continually with changing geometric configuration and complex project management involving multiple stakeholders from builders/ contractors to public and government. To facilitate better decision making and project execution of highway planning & construction, many tools are currently being employed to maintain smooth flow of traffic when construction is being carried out. Some of them are microsimulations, 3D/4D CAD models and other techniques. Project area traffic visualization along with proposed project geometry using 3D/4D CAD models can help better understanding of projects and identify challenges related to planning, construction phasing and traffic management which are overlooked by the tools that are currently being used.

READERS GUIDE

This thesis is comprised of six chapters. The following chapter introduces various phases in a transportation construction project. More detailed explanation is given on importance of traffic information during various project phases, identifying the type of information needed and how it can be used. Later, it describes briefly different types of traffic analysis tools that are currently used to model traffic conditions and their prime characteristics.

Chapter 3 explains the need for microsimulation and its advantages over other traffic analysis tools. It also describes general characteristics of microsimulation and how microsimulation analysis is done. Further, literature to support the need for traffic visualization in construction projects is presented with current practices being followed. The chapter ends with a recap on the applications of 3D/4D CAD models that are put forth in past research and discusses the scope of using traffic information with CAD models.

Chapter 4 describes the problem statement and research methodology adopted for this thesis to address the issues explained in the problem statement. The chapter mainly concentrates on the methodology adopted to collect traffic data from mesoscopic Dynamic Traffic Assignment (DTA) models, signal timing plan and other traffic related information. The modeling process is explained and the areas which are not covered under the scope of this analysis are also explained. Finally, the software used for each step of modeling is listed.

Chapter 5 is comprised of three case studies – two TxDOT projects illustrating the applications of 3D/4D CAD models with traffic data in various phases of construction and one case study to validate the vehicle volumes generated for microsimulation model from DTA models. The first case study, North Tarrant Express project illustrates applications during construction phase after schedule and Traffic Control Plans (TCP) are fully developed. The next case study, FM 2154 and George Bush Drive Intersection project shows how these models can be used to communicate TMP planning accurately during planning & design phase to the stakeholders. Final case study is the construction of JW Marriott hotel in downtown Austin. Detours are analyzed in traffic analysis tools and compared with vehicle counts on field for validation.

Chapter 6 covers conclusions from the research and provides recommendations for future work on the topic.

Chapter 2 Literature Review

Roadway construction projects involve many phases and are spread across many disciplines. For proper execution of a roadway project, diverse information is required viz., Right of Way (ROW) data, utility locations, traffic counts/peak hour durations etc., besides the geometry details for the proposed construction. This chapter tries to capture the importance of traffic information in major phases of roadway construction projects. This chapter is important to understand the activity during each phase of a project and the role of traffic information particular to that place. The types of traffic information required and the intended audience for each phase are described. Subsequently, a brief explanation is given regarding the traffic analysis tools that are being used for traffic analysis by various transportation agencies.

PROJECT DEVELOPMENT PROCESS

As per TxDOT manuals (TxDOT, Manual Notice 2012-1, October, 2012), a project development process consists of the following steps:

- Planning and Programming
- Preliminary Design
- Environmental
- Right of way and Utilities
- Plans Specifications and Engineering (PS&E) development
- Letting

Planning and programming

The need for roadway development and expansions is identified and authorization is sought from concerned authorities. Scope of the project is defined for planning compliance and submitted for construction funding.

Preliminary design

Considering the planning information, design concept of the project is framed during this phase and the resultant preliminary schematics are put forth for approval. Public meetings are held to seek approval of the preliminary schematics and feedback is used to further refine the schematics.

Environmental

Preliminary environmental clearances are sought for the preliminary designs after collecting environmental data of the proposed layout and its impact on nearby natural resources like waterways and floodplains is assessed. Environmental documentation stating all the survey information for the project need and its impact is filed and submitted for interagency coordination/permits.

Right of Way utilities

During this phase, preliminary right of way research is done with the District Right of Way office and required information is gathered. Boundaries of the existing ROW are established. Identification of parcels that are to be acquired for new ROW is done and owners of the property (residents and business owners) are helped with relocation assistance. Existing utilities are identified and cross-checked with as-built plans for any relocations during operations.

PS&E development

Detailed design is performed during this phase. All the required information from previous phases like traffic data, right of way maps, as-built plans, utilities data and other information are pooled to complete the geometry configuration of the proposed project. Traffic control planning is also done during this phase to facilitate efficient construction and maximize mobility/safety during construction. Alignments and profiles are finalized based on hydraulic data collected. Further, roadway and bridge design is done including signal planning, signing/striping and intelligent transportation systems. Utilities like drainages, culverts, retaining walls are also designed for construction.

Letting

Review of PSE’s is performed by factoring in the traffic operations, construction and general services and FHWA before issuance of construction bids. Funding approval and PS&E are sought before concluding the final proposal for the project. The contract is awarded after bid review. The construction phase follows after the bid is awarded.

TRAFFIC DATA IN DIFFERENT PHASES OF A PROJECT

Based on the above project phases, author arrived at a conclusion that the role of traffic information in decision making can be grouped and analyzed under the following phases after conducting interviews with TxDOT officials and researchers in Centre for Transportation Research (CTR):

- Project planning
- Design alternatives
- TMP planning
- Construction & Public Information

Project planning and design

Project planning is a fundamental and challenging activity in the management and execution of highway projects. Highway construction and other infrastructure projects are very sensitive as their execution impacts public convenience. Detailed planning is needed to reduce the impact of lane closures and delays on the commuters as well as residents in the vicinity of project work zones (O'Brien et al, 2012). Traffic data is necessary to analyze the extent of improvements to be made to existing facilities, the impact due to construction on existing road networks and future capacities of the transportation systems. Many DOT's use ITS traffic data to plan the lane closure schedule during construction and maintenance to reduce the impact on motorists. Hourly traffic volumeand/or speed data can tell when lanes should be closed and re-opened(Yu & Fengxiang, 2002). Hourly traffic volumes are also of value for pavement and bridge maintenance to determine the degree of infrastructure usage to estimate maintenance needs.

Needs for transportation projects is triggered by the estimation of future travel demands using traffic modeling and comparing them with current travel demand data (TxDOT, 2012). Depending on the requirement, the traffic data may include daily counts, vehicle classification, speeds, weights, directional factor, truck factor, and design hour factor. This data is typically needed for plans leading to construction, traffic improvements and pavement maintenance projects. Traffic forecasting data is also required for reconstruction, resurfacing, adding lanes, bridge replacement and major interchange improvement projects(FDOT, 2012). Traffic data reflects the effect of future traffic growth relative to historical trends, the addition of major development, the diversion of traffic to nearby facilities and the impact of capacity constraints.

The design of a road or any part thereof should be based upon factual data, among which are those relating to traffic. Cost, quality of foundations, availability of materials, and other factors have an important bearing on the design, but traffic indicates the service for which the road is being built and directly affects the geometric features of design such as width, alignment, grades, etc. Traffic information serves to establish the "loads" for geometric road design.

TMP planning

The aging of roadways and highways periodically requires reconstruction, maintenance and repair which result in construction work zones. Also, expansion of transportation systems often involves construction activity on an operating network where construction has to be carried out when the roadways are open to motorists. In addition, roadway traffic volumes are increasing rapidly even though the transportation system capacity is not. This results in added complexity in the execution of construction activities in an operating roadway facility. Considering the delays caused by the construction projects and safety concerns in the work zones, the Federal Highway Administration (FHWA) passed a regulation in 2004 to develop Transportation Management Plans (TMP) for road construction and maintenance projects (U.S. Department of Transportation Federal Highway Administration Office of Operations, 2005).

As defined by FHWA, “TMP lays out a set of coordinated strategies and describes how these strategies will be used to manage the work zone impacts of a project. The scope, content, and level of detail of a TMP may vary based on the agency’s work zone policy and the anticipated work zone impacts of the project.”(Federal Highway Administration, U.S. DOT, 2010). A TMP contain mitigation strategies to help in minimizing impacts such as delay and to provide safety in and around work zones. TMPs temporary traffic control plans. Some major projects may also contain transportation operations and public information components where greater impacts to safety and mobility are anticipated.

The efficiency of highway construction operations highly depends on appropriate traffic control measures taken throughout the project execution. Traffic control planning (TCP) should be taken-up hand-in-hand with construction activity planning and scheduling. Improper handling of traffic in the workzone can result in schedule delays due to traffic conflicts with construction operations, unexpected costs due to delays and most importantly, safety issues to the construction crews and commuters in the work zone (Russell et al, 1992). Research has suggested that studies should be performed on site characteristics and traffic patterns in the work zone to schedule the activities better and reduce costs. It was also emphasized that traffic analysis should begin during the planning phase with inputs from construction (Anderson et al, 1999).

Existing and future traffic conditions are required to develop project TCP. For the project area, the typical data needed will be- existing roadway characteristics (history, roadway classification, number of lanes, geometrics, urban/suburban/rural), existing and historical traffic data (volumes, speed, capacity, volume/capacity, percent trucks, queue length, peak traffic hours), existing traffic operations (signal timing, traffic controls), traffic growth rates (for future construction dates), and traffic predictions during construction (volume, delay, queue). Construction phasing and staging greatly affect the safety and mobility of work zones. TMP planners consult with traffic engineers and traffic operations personnel to obtain the aforementioned data for developing construction phasing/staging plans (U.S. Department of Transportation Federal Highway Administration Office of Operations, 2005). Hence, it can be said that existing and predicted future traffic data plays an important role in formulating and implementating TCPs in project work zones.

Construction and public information (PI)

Public information to road users and the nearby community forms an important component of the project team’s efforts to reduce work zone impacts by providing zone specific and updated information. This not only improves safety conditions for construction workers in the work zone but also mitigates potential impacts on both safety and the level of service of the commuters while using the road in the construction zone (U.S. Department of Transportation Federal Highway Administration Office of Operations, 2005).

In addition to the travel lane information (partial and complete lane closures), traffic data also plays an important role in conveying the workzone information to commuters. DOT's collect traffic volumes in project work zones to assess the peak volume hours. Motorists can be encouraged to use alternative routes or plan trips to avoid the peak traffic hoursso that congestion can be managed effectively during the project construction. Based on historical data, travel demand is predicted for the work zone.However, if the collected traffic volumes are higher than the predicted, travel speeds in the work zone can be assessed with the real-time data and disseminated in regular intervals corresponding to the changing traffic. Travel times and construction delays can also be conveyed to motorists in the work zone to enforce appropriate driving and travel behavior (Mai, 2009).

From the above discussion, the importance of traffic information and phases ofthe project where it can be used in different phases of project can be tabulated as

Challenges	Conceptual Planning	Design alternatives	TMP Planning	Construction
Communication	✓✓	✓	✓✓	✓✓
Traffic control	✓✓	✓	✓✓	✓✓
Workzone management	✓	✓	✓✓	✓✓

Legend:

✓✓ - Major relevance to the phase

✓ - Minor relevance to the phase

Table 2.1: Usage of traffic information in various construction phases

TRAFFIC DATA MODELING

The Intermodal Surface Transportation Efficiency Act (ISTEA) has legislated deployment of sophisticated hardware and software system management methodologies to predict and evaluate various improvement plans without the inconvenience of a field experiment, to manage traffic and control the existing roadway networks capacity(FHWA, 2004). Traffic analysis tools were developed using software packages, methodologies and procedures for

- Simulating and optimizing the operations of transportation facilities and systems
- Modeling existing operations and predicting probable outcomes for proposed design alternatives
- Evaluating various analytical contexts, including planning, design, and operations/construction.

Traffic analysis tools are being used by practitioners to

- Improve decision making process

- Evaluate and prioritize planning/operational alternatives
- Improve design and evaluate time and costs
- Reduce disruptions to traffic
- Present strategies to the public/stakeholders
- Operate and manage existing roadway capacity
- Monitor performance of existing facilities

Different types of traffic operations analysis tools that are commonly employed are (Dowling et al, 2002):

Planning models

Planning tools allow for the evaluation of specific projects or alternatives without conducting an in-depth engineering analysis. Such techniques are primarily used to prepare preliminary budgets and proposals, and are not considered to be a substitute for the detailed engineering analysis often needed later in the project implementation process. Sketch-planning approaches are typically the simplest and least costly of the traffic analysis techniques. Sketch-planning tools perform some or all of the functions of other analytical tool types, using simplified analyses techniques and highly aggregated data. However, such techniques are usually limited in scope, analytical robustness, and presentation capabilities.

Highway Capacity Manual (HCM) models

HCM models are designed for operations analysis of isolated segments and points of transportation systems. These models are good for predicting capacity, density, speed and delay, but are less accurate at predicting the extent of congestion and queuing that may occur when demand exceeds capacity.

Macroscopic simulation models

Macroscopic simulation models are based on the deterministic relationships of the flow, speed, and density of the traffic stream. The simulation in a macroscopic model takes place on a section-by-section basis rather than by tracking individual vehicles. Macroscopic models have considerably fewer demanding computer requirements than microscopic models. However, they do not have the ability to analyze transportation improvements in as much detail as the microscopic models.

Mesoscopic simulation models

Mesoscopic simulation models combine the properties of both microscopic (discussed below) and macroscopic simulation models. As in microscopic models, the mesoscopic models' unit of traffic flow is the individual vehicle. Their movement, however, follows the approach of the macroscopic models and is governed by the average speed on a particular route. In this casse, travel simulation takes place on an aggregate level and does not consider dynamic speed/volume relationships. As such, mesoscopic models provide less reliability than the microsimulation tools, but are superior to the typical planning analysis techniques.

Microscopic simulation models

Microscopic models simulate the movement of individual vehicles based on car-following and lane-changing theories. Typically, vehicles enter a transportation network using a statistical distribution of arrivals (a stochastic process) and are tracked through the network over small time intervals (e.g., 1 second or a fraction of a second). Typically, upon entry, each vehicle is assigned a destination, a vehicle type, and a driver type. Computer time and storage requirements for microscopic models are large, usually limiting the network size and the number of simulation runs that can be completed.

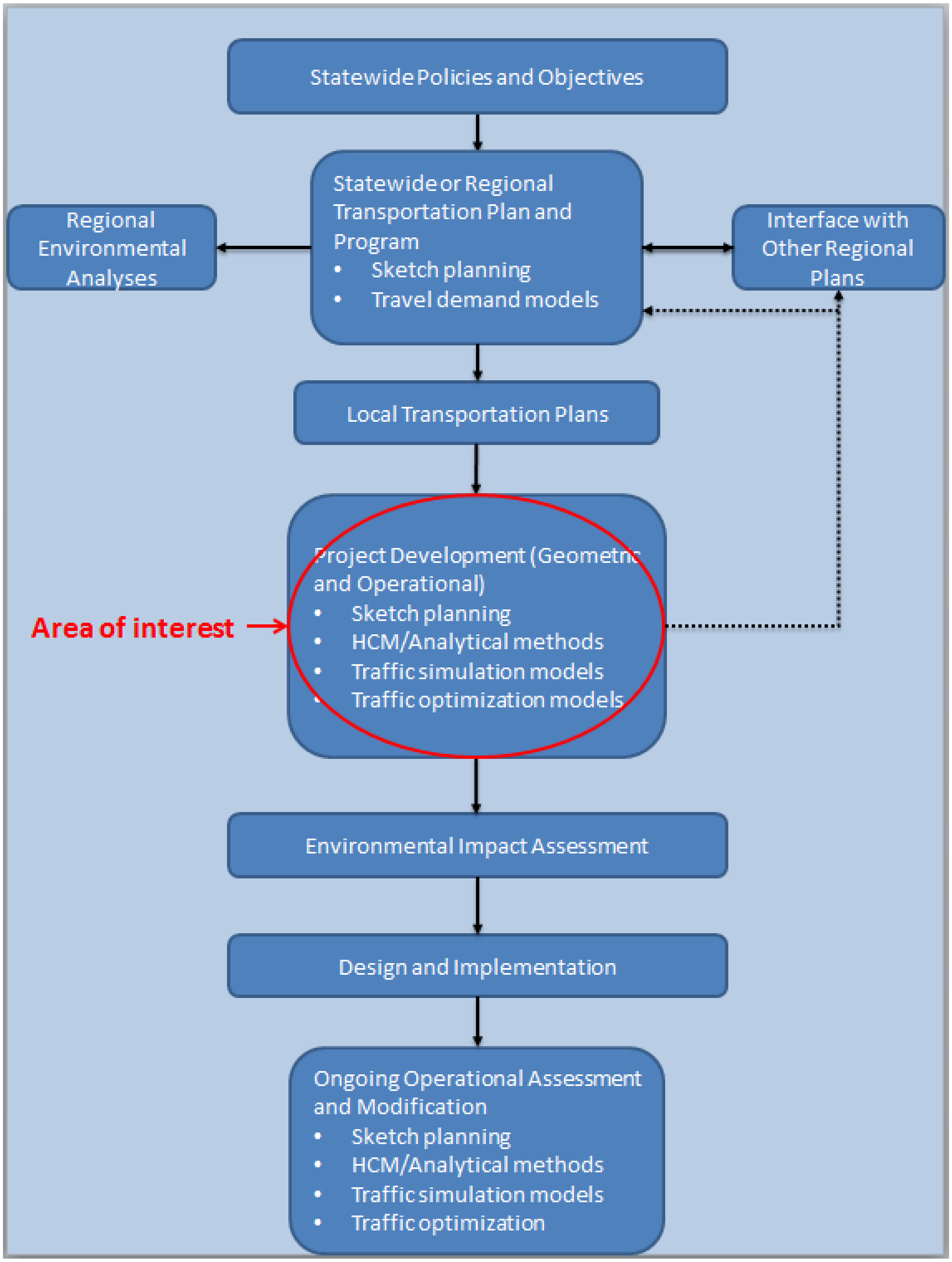


Figure 2.1 Overview of transportation analysis process (FHWA, 2004)

Figure 2.1 presents an overview of the transportation analysis process, along with its various evaluation contexts and the types of traffic analysis tools that are typically used in each context. It can be seen that project development usually involves the application of more rigorous and detailed techniques, such as traffic simulation and optimization.

Among the types of traffic analysis tools described, Table 2.2 presents the general relevance of each tool category for each analytical context including planning, design, and operations/construction.

Analytical Context	**Analytical Tools/Methodologies**						
	Sketch Planning	Travel Demand Models	Analytical Deterministic Tools (HCM-Based)	Traffic Optimi zation	Macroscopic Simulation	Mesoscopic Simulation	Microscopic Simulation
Planning	●	●	Φ	○	Φ	Φ	○
Design	N/A	Φ	●	●	●	●	●
Operations/ Construction	Φ	○	●	●	●	●	●

Legend:

● Specific context is generally addressed by the corresponding analytical tool/methodology.

Φ Some of the analytical tools/methodologies address the specific context and some do not.

○ The particular analytical methodology does not generally address the specific context.

N/A The particular methodology is not appropriate for use in addressing the specific context.

Table 2.2: Relevance of traffic analysis tools with respect to analytical context (FHWA, 2004)

Chapter 3 Microsimulation Visualization

NEED FOR MICROSIMULATION

The traditional models like macroscopic models and mesoscopic models are generally ineffective in evaluating strategies designed to influence travel choices and optimize system performance. Also, they cannot capture traffic dynamics, intersection control delays, vehicle-pedestrian interactions, geometric design impacts or traveler-specific responses to route-guidance systems. Microscopic models overcome these limitations through their ability to model detailed system operations and analyze the management strategies, when provided with details about transportation facilities and observed travel behavior. The use of microscopic models is warranted for their capabilities to simulate, analyze and visualize congested traffic conditions. Visual animation of the traffic conditions can help to increase understanding of the modeling process and demonstrate to the key stakeholders (Sbyati & Roden, 2010).

As noted in Table 3.1, microscopic simulation (also called 'microsimulation') can be used for themajority of roadways that are commonly built in a transportation system. This flexibility makes microsimulations more advantageous than macroscopic or mesoscopic models. Also, microsimulation models have the ability to provide animation of how traffic will operate in the modeled network. Individual vehicles can be viewed traveling through the network, interacting with other vehicles and responding to traffic controls. This is valuable for transportation project teams to analyze traffic operations during construction and modify the TCPs to reduce inconvenience to motorists and improve safety in the construction work zone. Microsimulation models have been widely used to educate and inform the public about traffic operations during proposed construction projects and after (Waite & Szplett, 2005).

Relevance of Traffic Analysis Tool Categories with Facility Types							
Facility type	Analytical Tools/Methodologies						
	Sketch Planning	Travel Demand Models	Analytical Deterministic Tools (HCM-Based)	Traffic Optimization	Macroscopic Simulation	Mesoscopic Simulation	Microscopic Simulation
Isolated Intersection		◆	●	●	●	●	●
Roundabout			●		◆		◆
Arterial	●	●	●	●	●	●	●
Highway	●	●	●	◆	●	●	●
Freeway	◆	●	●	◆	●	●	●
HOV Lane	◆	●	◆		●	●	●
HOV Bypass Lane		●		◆	◆	◆	●
Ramp	◆	●	●	●	●	●	●
Auxiliary Lane			◆	◆	●	●	●
Reversible Lane		◆					◆
Truck Lane		●	◆	◆	◆		●
Bus Lane		●			◆		●
Toll Plaza		◆	◆				●
Light-Rail Line		●					●

Legend:

● Specific content is generally addressed by the corresponding analytical tool/methodology

◆ Some of the analytical tools/methodologies address the specific content and some do not

Table 3.1: Relevance of traffic analysis tool categories with facility types (FHWA, 2004)

MICROSIMULATION

Microsimulation is a dynamic and stochastic modeling of individual vehicle movements within a system of transportation facilities. Each vehicle is moved through the network of transportation facilities on a split second by split second basis according to the physical characteristics of the vehicle, fundamental rules of motion and rules of driver behavior (Dowling et al, 2002).

Microsimulation typically includes a combination of procedures for identifying the location, speed and acceleration of vehicles in the highway network at each moment of time. A set of relatively simple rules is used to move the vehicles through the network. Statistics are tabulated on the vehicle activity, and two outputs are generally produced – text reports and visual animations.

General characteristics of microsimulation models

Time steps

The simulation of vehicle movements is done in a series of time steps. The vehicle position, velocity, and rate of acceleration/deceleration are computed at the end of each time step andsummary statistics are collected on the results.The number of time steps per second influences both the accuracy and duration of a microsimulation model run. The more time steps per second, the greater the potential precision of the model results.

Randomization

Microsimulation models are to be randomized for better results as they produce the same pattern and represent similar behavior in all the runs without randomization. Computer software uses a random number generator to generate each set of random numbers. The generator requires a starting number, or "seed" to produce a unique sequence of numbers. Different seed numbers can be used to vary performance of the model.

Vehicle generation

Vehicles are generated by the simulation, at the start of each step in the microsimulation. Vehicles are generally released from the start or end of a link based on the input given. Also driver behavior attributes are typically assigned to increase the reality of the simulation. In addition, vehicles are described based on their length, width, maximum speed, accelerating rates and the braking rates.

Path choice

For every vehicle travelling on a road link, a destination is assigned. This can be done by assigning path choices for all vehicles travelling on a link. Origin-destination tables can be used to allow dynamic path choices based on congestion encountered along the way.

When origin-destination tables are not used for path choices, then vehicles follow user specified routes.

Vehicle movement rules on links

A link is a section of a road/street where street geometry and demand are constant so that the section of street can be modeled as a pipe, with vehicles entering the pipe at one end and leaving at other end. In microsimulation models, three basic movement rules are assigned to any vehicle on a link: single vehicle, car following and lane changing.

Single vehicle on a link: It is similar to the condition as if no other vehicles are present when a vehicle travels on a road. The vehicle moves at free-flow speed of that particular link.

Car following rule: This is the situation in which a vehicle travels behind another vehicle at a speed less than the free-flow speed while maintaining headway (gap between two vehicles) as specified in the input.

Lane changing rule: Lane changing facilitates movement of vehiclesbetween lanes when an acceptable gap is available for merging. The probability of a vehicle merging into another lane is calculated based upon the speeds of vehicles in both lanes.

Vehicle movement rules within the intersection (at the node)

Vehicles can be ordered to facilitate which lane vehicles have higher preference at controlled intersections. The vehicle speed can also be altered at an intersection. The reduced speed may be customized to a particular turn movement.

Examples of Microsimulation software are: CORSIM, VISSIM, Simtraffic, andTransmodeler. These software are capable of stochastically modeling individual vehicle movements as function of time and space.

Typical microsimulation analysis steps

1. Project scope
2. Data collection
3. Model creation
4. Model checking
5. Calibration
6. Alternatives testing
7. Results

Before starting a microsimulation it is recommended to assess exactly what the analysis is to accomplish. In order to achieve this, identifying the project objectives, scope of the project and appropriate approach is very important.

Project scope

Project scope is needed to set the geographic and temporal bounds of the analysis, the temporal bounds of the analysis, the range of alternatives to be tested and the numerical output to be produced. A microsimulation in general has moderately large geographic bounds and a user defined time frame.

Data collection

Data collection involves collecting the necessary input data for microsimulation model and the output data to calibrate the model.

The required model input data are:

- Geometry – Lanes, curvature
- Controls – Signal timing, signs
- Existing demands – Traffic flows, turn movements

Data collection also includes use of aerial photos, agency files and field measurements to obtain the input data. The scope of the model defined by area boundaries, intersections and highway segments is also identified. Intersection and highway segment geometry can be obtained from aerial photos and field inspection. Signal control data can be obtained from the agency operations/TCP files.

Existing demand and turning movements at intersections can be measured in the field or can be extracted from operational DTA models.

Model creation

In this step the data collected on network geometry, control and demands is input into the microsimulation model. The basic steps of modeling are:

- Model network geometry (lanes, lengths, etc.)
- Model control data (signs, signal timing)
- Model demands

In brief, modeling can be summarized as:

- Import and size overlay image (aerial photo or as-built CAD file) for network creation as per the right co-ordinates
- Rough drafting of links and node locations over aerial photo
- Create link attributes(lanes, free-flow speeds)

- Create intersection attributes (control type, control parameters, turn lane designations, stop bars, turn pockets)
- Create source/sink zones or nodes
- Createroute attributes and origin-destination tables/vehicle flows
- Review/Revise default global parameters (vehicle characteristics, vehicle mix etc.)

Error checking

The initial network coding for the microsimulation model is checked in this step. The steps followed in error checking are:

- Check routing attributes for proper vehicle movements as intended
- Review intersection attributes for turn movements
- Review demand inputs at the start of links
- Run model at very low volumes to identify errors
- Trace selected vehicles through the network

Calibration

Calibration is determining if the simulation model is reasonably consistent with the real scenario. The calibration process involves error checking to make sure that the inputs and default values of the fixed parameters are assigned as desired. The most frequently used approach is to collect field data for the network of interest and compare model results with the field data. The model is then tuned against this data if any discrepancies are identified.

Alternative analysis

The model is run to test various alternatives. Coding of alternatives and testing involves some baseline forecast of future demand. The existing network is then edited for each alternative. Finally, the model is run numerous times for each alternative and statistics are gathered from the model reports.

Results

Microsimulation results can be represented in numerical or graphical format. Most of the existing microsimulation software supports graphical representation of a road network with vehicles. Numerical results can be reported in text files with accumulated statistics on the performance of the network. Presentation of results depends upon the intended audience for the simulation. Traffic engineers can understand reports generated in text files for review of vehicle simulation whereas for the non-technical audience like public and government bodies, results can be shown in graphical/animation format.

The effective presentation of traffic impacts to the public is an essential part of the approval process for proposed transportation changes. Many transportation agencies use the results of a microsimulation program as a basic data source that is combined with corresponding visual aids to create technically effective and more appealing presentations (Garrick et al, 2005).

Microsimulation models are mainly used to investigate the operational effects of the geometric design of the proposed project. They can be used to analyze route location, planning of alternatives and support decision-making process. The same thing can be applied to construction too. A visual representation of traffic that can be imported from microsimulation to CAD models can help one to reproduce the actual traffic conditions in construction work zones and also the accurate geometry at any point of interest. However, traffic simulation requires extensive manual labor to input the different kinds of traffic data into simulation programs.

TRAFFIC VISUALIZATION IN CONSTRUCTION PROJECTS

A significant difference between construction scheduling for standard projects and highway interchange projects is that the construction phasing of the latter is directly related to the traffic planning. Accordingly, contemporary and future tools should allow for the integration of traffic planning, and effective communication of traffic control decisions. It should also allow for the visual evaluation of various traffic control options during project construction(Liapi et al, 2003).

Traffic simulation visualization provides the capability to view traffic information that is output from various traffic analysis tools, added to a 3D model and can be displayed as animation. Traffic analysis tools can provide data in 2D or in 3D space. Visualizing the traffic simulation enables project teams to evaluate the traffic performance of the design within the virtual models, without waiting for the construction to begin. Instead of evaluating the numerical traffic data and geometric design separately, combining visualization of the output from traffic microsimulation models and 3D geometric models will result in a real-time simulation demonstrating not only the project configuration but also the future behavior of the traffic realistically. The 3D simulation of moving vehicles can also be valuable when the proposed designs are visualized from the driver's perspective with fully-loaded traffic conditions (FHWA, 2010).

Traffic visualization can be implemented in either 2D or 3D space. Figure 3.1 shows an example of traffic simulation of a proposed roadway improvement based on a 2D model. The background image is imported from a digital photograph. The proposed roadway (intersections, number of lanes etc.) is overlaid on the background image. Traffic simulation in 2D can reflect the actual traffic volumes, vehicles, roadway geometry and signal control plan used in the design. Traffic simulation in 3D can also be implemented as shown in Figure 3.2. In addition to features of 2D traffic simulation, background detail such as sky, trees, buildings etc., can be added for life-like realism. 3-D traffic simulation can include not only the views of traffic and geometry but also the driver perspectives through when driving through the project area.

Figure 3.1 Microsimulation in 2D(Garrick et al, 2005)

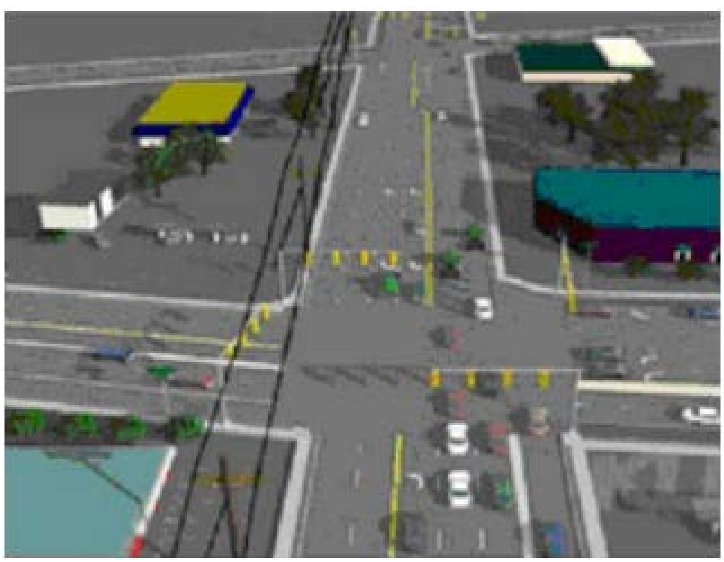


Figure 3.2 Microsimulation in 3D(Garrick et al, 2005)

2D traffic simulation can reach a medium level of visual realism using CAD drawing or aerial photographs as background images. The loss of realism is due to rudimentary road geometric features (such as intersection, median) that are typically generated by traffic simulation software and loss of perspective view of the roadway geometry. Visualization of traffic in 3D (figure 3.2) within a microsimulation program does not perform much better than 2D visualization. This is due to relative simple 3D modeling in the traffic simulation software compared to the 3D engineering software that are being employed for project visualization. (Wang, 2005). Photorealistic 3D visualization is generally developed from a standpoint of enabling the involved stakeholders (both engineering and non-engineering) to arrive more quickly at a common understanding of the more 'physical' elements of a proposed design (e.g., geometric design elements, spatial location, likely visual appearance from the standpoint of different users, signing, surface markings, etc.). The absence of photo realistic detailing in microsimulation graphic outputs orients the audience to focus more on the operational effects of designs, while highly realistic visual simulations can improve the comprehensive understanding of a proposed facility. Previous research had strongly recommended the merger of analytical microsimulation modeling and visual simulations like CAD models to enable highly realistic, real time, graphic output capabilities (Hughes et al, 2007). In addition, 3D visualization with geometrical accuracy may enable the detection of potential errors in simulation results, which is hard to achieve with tables and 2D maps.

CAPABILITIES OF 3D/4D CAD MODELING

The transportation industry has been benefitting from 3D modeling in many ways (Gau, 2009). Unlike building and other vertical construction projects, transportation projects have a wide area of impact be it Right of Way (ROW) acquisition, level of service to the motorists in the project area and local business that get affected. The visualization capabilities of 3D models were instrumental in receiving public approval for infrastructure projects during public meetings and between State Departments of Transportation (DOT's) and the public (Gau, 2009). 3D/4D CAD models also play a prominent role in improving communication and understanding of the project in both the design and construction phases. During the construction phase, CAD models are used for detecting spatial conflicts and utility conflicts which are difficult to identify using traditional 2D drawings(Schmeits, 2011). Using 4D models, other project aspects like ROW acquisition, work sequencing and traffic phasing may also be reviewed, and potential delays can be avoided pro-actively. 3D and 4D CAD models also proved to be a valuable asset in work area management pertaining to placement of equipment and material logistics (O'Brien et al, 2012).

During the construction of a highway interchange project, the continuously changing geometric configurations affect traffic planning decisions and complicate the overall project management. Without a good understanding of the changing 3D geometry of the structure during construction, traffic control strategies are difficult to optimize and implement effectively (Liapi et al, 2003). 3D/4D CAD models, which are effective in communicating project planning and schedule information, should also allow for the integration of traffic planning and visual evaluation of various traffic control options during project construction.

Figure 3.3 Traffic control measures for construction(Liapi et al, 2003)

3D/4D CAD models illustrated their capability in rapidly visualizing and analyzing traffic management strategies at different stages of the construction process. Using 3D/4D CAD modeling can alleviate the complexity of devising traffic management plans for transportation projects (Goyat, 2012). However, 3D/4D CAD models were not used to study the impact of construction activities on traffic during construction, to analyze the phasing and traffic management plans, considering both construction and moving traffic. Until date, mutual interaction between construction and traffic was analyzed on different platforms viz., 3D/4D models for construction, DTA models and microsimulation for traffic impacts.

When microsimulation models are presented to a non-technical audience (e.g.: public, funding agencies), it is observed that the public generally has difficulty orienting themselves to the intersections and the locations being shown in the simulation models

(Waite & Szplett, 2005). Since 3D/4D CAD models are a very efficient tool in virtually re-creating the real geometry conditions and landmarks with the advanced rendering capabilities available with fewer efforts (Schmeits, 2011), combining both traffic simulation models and CAD models would help better understanding of traffic operations during construction. Improved inter-operability and computational capacities of software have facilitated exchange of data from microsimulation software to CAD modeling software (Goyat, 2012). Goyat in his Master's thesis demonstrated the capability of current CAD modeling software to visualize traffic along with 3D geometry. Taking advantage of this development, output from microsimulation can be used in CAD models to develop comprehensive models for roadway construction project management.

Currently, vehicles are visualized to show vehicle movements during construction detours and after construction of proposed facilities. In the LBJ expressway project, by using TCPs and placing 3D vehicle objects along open lanes animations were created to represent travel lanes available during construction. A member of the research team is actively involved in updating 3D/4D CAD models with TCPs and generating animations for communication through local media and social networking webpages of the project (Goyat, 2012). Wyoming DOT, in the Wyoming Diverging Diamond Interchange project, used 3D object files in 3D geometry models to generate videos conveying traffic movement from above the interchange as well as from a driver's perspective (Bentley systems, 2012). Display of those videos at public meetings helped the public understand how the interchange would look and work. Though these representations improved communication to an extent, the degree of reality with respect to vehicle animations was a constantly raised issue. Simulation of vehicles in virtual models without complying with actual traffic volumes can sometimes mislead the audience during communication of project scenarios and details. Hence there is a need of using actual traffic information during communication for credibility and justification of project need and planning. Also, lack of 3D representation of construction geometry might result in lack of perspective of changing geometry during design of TCP by TMP planners/traffic engineers.

The previous paragraphs explained the need for microsimulation modeling and the process for developing a model. Though microsimulation modeling software possess basic visualization capabilities, the disadvantages of those are detailed and improvements to add more meaning to microsimulations are suggested. Capabilities of 3D/4D models are briefed based on past research and their value towards improving project review and communication. As mentioned earlier, 3D visualization of surrounding project geometry is necessary to review the extent to which existing infrastructure can be used for traffic detouring instead of constructing temporary pavements, which can escalate project cost and duration. Having explained the areas which can be improved by the integration of traffic information with 3D/4D CAD modeling, a specific approach is described in the following chapter that can facilitate the integration. The criteria to be defined for the analysis and validation of models are also explained.

Chapter 4 Research Methodology

Based on the literature review in previous chapters, a framework for visualization of microsimulation traffic data with 3D and 4D CAD models is described in this chapter. The phases of project to be analyzed are identified, development of results and validation of the results are explained. The feasibility of benefits observed in the literature is studied using two case studies on transportation projects that are in different phases of project development.

PROBLEM STATEMENT

Previous research suggests creation of a single platform to analyze both traffic information and geometry details of construction projects. The main objective of this report is to explore the applications of visualizing traffic information in construction 3D/4D CAD models to overcome the decision-making and communication challenges identified in previous chapters. The potential benefits that result through integrating traffic information with CAD models will be explored. Currently, road geometry configuration and traffic impact during construction are being analyzed on different platforms viz., 3D/4D CAD models for construction and microscopic/mesoscopic traffic simulation for traffic analysis (FHWA, 2010). Based on the discussion in previous chapter, it is evident that 3D/4D CAD modeling is capable of adding traffic data for visualization. In this thesis, the integration is performed using geometry modeled in 3D CAD models and traffic data from microsimulation models.

The process adopted to accomplish visualization of traffic in CAD models will be explained in detail and once visualization is accomplished, the areas in which the integrated models are analyzed for is also explained. Additional benefits that are implied with visualization of dynamic traffic in virtual reality, which is not being done on a large scale for construction projects, that can be beneficial from conceptual planning to construction and traffic management are also mentioned. Assumptions that are taken while modeling traffic data and also the assumptions while analyzing CAD models with traffic will be mentioned.

ANTICIPATED BENEFITS OF TRAFFIC VISUALIZATION IN 3D/4D CAD MODELS

Visualization of traffic with 3D/4D CAD models offer potential benefits in more than one phase of project development process by helping in understanding both the geometrical and operational design during planning/design phase;reviewing traffic control during TMP planning phase, communicating the construction phasing with traffic detour scenarios in work zones in a realistic approach to the stakeholdersduring construction and predicting the performance of a facility after construction.

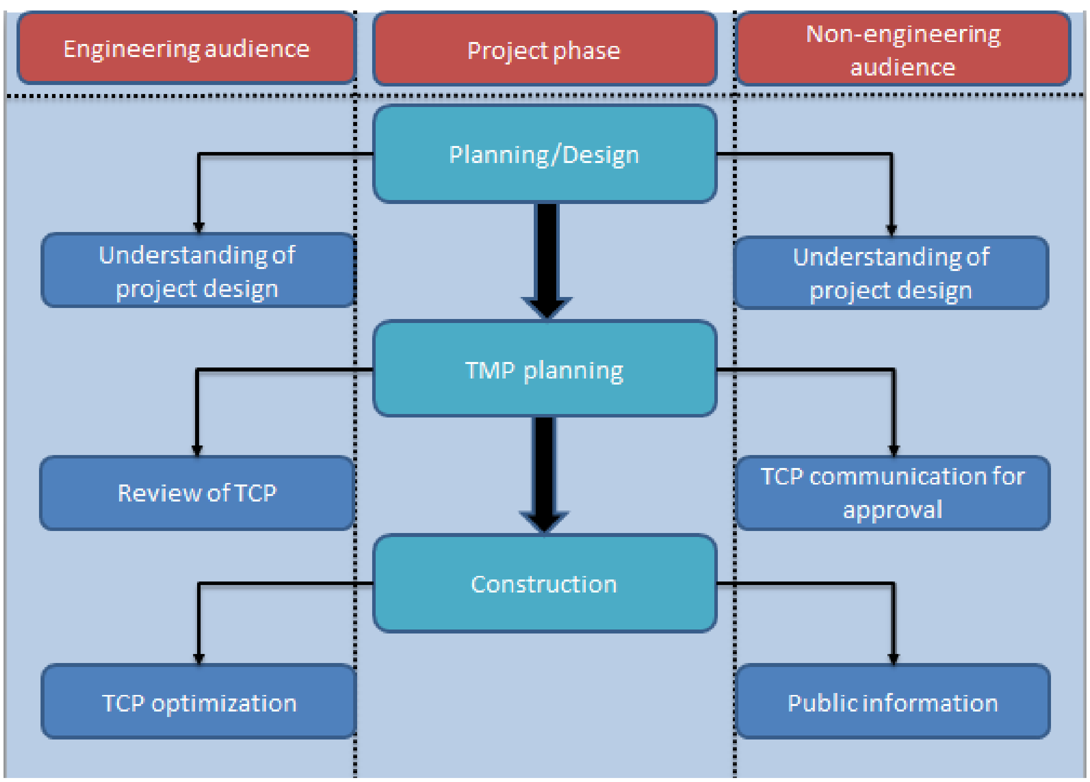


Figure 4.1 Benefits of traffic visualization with 3D/4D CAD models

METHODOLOGY

The work flow to integrate traffic information with CAD models is similar to that of (Goyat,2012) but with a change that the construction schedule based 4-D models are not used for geometry when importing microsimulation traffic data into the CAD models. The reason for this being a lack of sufficient detail in scheduleswhen phasing is done for huge projects like NTE (Chapter 5). Moreover, fully developed schedules may not be available if the analysis is performed during TMP formulation phase.Alternatively, TCPs were utilized in addition to construction schedules forgeneration of accurate geometry in the time period for which microsimulation analysis was run. This facilitated creation of accurate geometry which was not reflected by the schedule. In general, changes in schedule also result in changes to TCPs as lane closures and widenings are conditional to prior completed activities. Usage of geometry from updated schedules for traffic simulation does not accommodate the changes that are made to TCPs due to schedule updates.

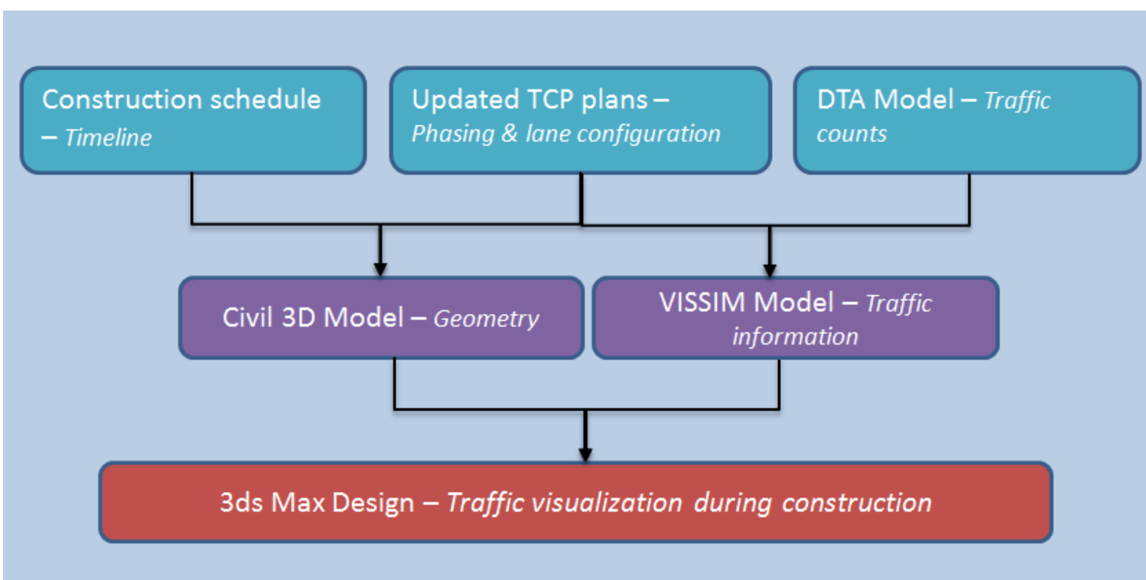


Figure 4.2 Flow chart for traffic visualization in 3D/4D CAD

SOFTWARE

3D geometry is created in Autodesk Civil 3D®, whereas 4D simulations are developed to analyze schedules in Navisworks®. 3D geometry and traffic data are combined in 3ds Max® and the same program is used for advanced visualizations. PTV VISSIM is used for the creation of microsimulation models. VISTA® is used to run DTA models to extract volumes. Neither the authors nor TxDOT has any monetary interest in PTV America, Inc., the company that owns copyrights to VISSIM or Autodesk, the company that owns the copyrights to Civil 3D, Navisworks and 3ds Max. The same can also be done using other software available which are mentioned earlier.

DATA COLLECTION

Data collection involves gathering the required information to develop 3D models and microsimulation models. Increase in computational power made it easier for developing software which can perform microsimulation analysis and also can export the file in a compatible format to CAD modeling software. From literature review, it is evident that microsimulation needs traffic volumes, turning movement information and signal timings as inputs. However, it is challenging to collect information for a particular area of interest as it is a very time consuming and expensive task. DOTs and other transportation operations agencies normally use macroscopic/mesoscopic models for their operations and planning(Chiu, 2011). Use of these macroscopic/mesoscopic models for traffic information can make the analysis less time intensive and also reduce the efforts. The author collaborated with a transportation graduate student, Mason Gemar, and worked on Dynamic Traffic Assignment (DTA) models for extracting peak hour volumes and turn movement information from them.

DTA models are being developed by Centre for Transportation Research (CTR) for Texas state road networks. These models are used for generation of microsimulation input data. DTA models are analyzed in a program named VISTA. VISTA models consist of individual vehicle information for the period in which it is analyzed. From this, time-dependent network performance of vehicles can be calculated, but due to the limitation of traffic simulator that is implemented within the DTA network, the performance metrics (like vehicle turning, yielding and stop) does not take into consideration all required characteristics. Hence, DTA outputs are being used to generate microsimulation models for better performance metrics. The graduate student with whom the author worked developed a process to generate microsimulation inputs from DTA models.

Among the three methods developed for extracting information out of DTA models, the method with vehicle flows and turning movements is used for generation of microsimulation input data. In this approach, the vehicle trajectories in the DTA model are translated into vehicle inputs at the periphery of the microsimulation network, and turning movements at the corresponding intersections. This provides two categories for inputs: vehicle inputs and routing decisions at an intersection or a junction. This method has implementation ease as a major advantage although the routing decisions on each route have to be manually coded. One more disadvantage is that for a particular peak hour consideration, the turning movement probabilities remain constant which may not be the same in a real situation.

Signal timing plans and lane configuration of the project area during construction are obtained through review of TCP plans issued by TxDOT for development of 4D models. TCP plans are 2-D representative plans with minimum detail of explanation in terms of words. The author spent a substantial time in figuring out how construction is being done as one of the case studies is a huge project, which is divided into 4 major phases, and each phase of construction had 5 to 6 sub phases. To develop the lane configuration for microsimulation during construction, all the lanes that are partially closed and completely closed are to be looked for because these lanes will not be carrying traffic anymore and the volumes have to be zeroed during analysis. At the same time, the traffic volumes must be added to adjacent lanes that are open and carrying traffic.

Next will be the geometry modeling in 3-D for different case studies. Unlike microsimulation, where the same procedure can be used for all case studies, it is not the same in the case of geometry modeling as the project phase defines the information available for modeling. Also, the objectives of case studies with respect to the project phase in which they are being analyzed are different from one another. Visualization of fully developed and approved TCP for construction, preliminary study of TCP planning using existing geometry and traffic information, conveying TMP strategies to the public using enhanced visualization capabilities assisted the DOT to receive public approval. Hence the type of information needed to generate geometry will be different for each project.

MODELING & APPLICATIONS

The model creation and their applicationin case studies are as follows:

Model development

Based on the construction phase the project is in and the scope of work, the objectives of modeling are defined. Level of detail of elements in the model is chosen considering the type of analysis that is being done.Every roadway construction project generally has vast amounts of data including plans, drawings, TCPs and schedules. Filtering of needed information in the early stage of modeling is necessary to i). Check for any missing information and ii). Estimate the level of effort needed to develop all the information collected into 3-D models.

Using the alignment, profiles and number of lanes from design schematics and as-built plans, 3-D models are developed. TxDOT monthly interim schedules are used for construction sequencing analysis for ongoing projects. Once the 3-D geometry modeling is completed, outputs from microsimulation and 3-D models are input into the third software set to visualize traffic and perform analysis. Details of modeling process are elaborated in Goyat's thesis (Goyat, 2012).

Using the model& validation

The primary goal of studying the construction phasing, TMP planning and building these models is to share project information with the stakeholders prior to any construction to receive feedback and eventually seek approval to continue with detailed designs or modify the proposed designs. Ideal case would be presenting the results from these models in public meetings and project team meetings to educate the involved personnel with project details. Feedback from these meetings could be used as a basis to judge the effectiveness of traffic visualization models in achieving the perceived benefits.

The criteria chosen to evaluate the application of these models are to examine how many of the challenge areas, identified in Table 2.1, are addressed with these visualizations. Literature review emphasizes the accuracy of traffic visualization to justify project planning and phasing. These CAD models with traffic visualization arealso evaluated for their enhanced capabilities in communicating the TCPs and construction phasing plans when compared to the previous methods viz., using 3D fly through animation with static vehicles and 4D animations. The effectiveness of these models in making the users understand traffic operations with changing geometry is presented in the case studies as an additional criterion.

Unfortunately, public meetings are not held during the span of research to present the results and evaluate these models. However, these results are displayed to traffic engineers, researchers and non-engineers in a research symposium organized by Centre for Transportation Research. Feedback is collected using a small survey and the results are graphically shown in case studies. In addition, additional benefits that are identified during this process are also documented in the case studies.

Both geometric and traffic models are validated to reflect actual conditions. Geometric models are compared to project images to the extent available. Google maps® was also used to validate existing geometry wherever necessary. For traffic model validation, a small case study is taken up to which field access is easily available and is less time intensive. As the traffic data collection approach from DTA model is still in evolving stage, the extent to which the data can be relied upon is tested in the case study (Chapter 5).

AREAS NOT MODELED

Virtual modeling is a vast domain. There is no limit to the level of detail that can be shown in virtual models to exactly represent the real conditions. However, considering time limitations and value addition that the level of detail can add to a final audience, modeling detail is limited to existing and proposed geometry. In the NTE case study, temporary pavements on IH 820 mainlines are not shown as the prime focus was on the

Beach street intersection which runs below IH 820. The analysis was in no way affected by the geometric details of 820 mainlines. Hence, temporary pavement modeling is avoided in all the construction phasing models developed.

Construction detours are always communicated through traffic control devices like detour signs, traffic cones and digital information boards. Though visualization of real conditions is the focus of modeling, traffic control devices are not added to the models. One reason for doing this is that there is a possibility that the models might be cumbersome and non-technical audience may get overwhelmed if a lot of detail is shown. Lane markings are used to give a general idea of detours in this analysis.

Since collecting traffic information from the DTA model is time effective and reduces the duration of analysis, this approach is chosen. However, no comparative analysis is made in the case studies on how planning or construction decision making is affected if the source (field counts, loop counters, historical data) of traffic information varies.

This methodology is the next step to previous research methods developed by Goyat (Goyat, 2012), where the analysis was aimed at studying the applications of 3D/4D CAD models for traffic management planning. Previous methodology focused at adding value to the process of traffic management planning by compiling the information into a single tool, reviewing the plans and communicating to the intended audience. TCPs were evaluated by creating multiple models for each TCP phase and analyzing it for constructability issues, conflicts and improvements. However, vehicle traffic was not used for the analysis. The effect on geometry construction due to TCP phasing was analyzed to the most extent. As mentioned earlier in this chapter, the current methodology aims at determining how traffic visualization in 3D/4D CAD models can enable better understanding of the construction as well as TCP phasing and improve communication with the stakeholders. Two case studies are presented in next chapter to justify the benefits that are mentioned in this chapter.

Chapter 5 Case studies

The current chapter illustrates the benefits of visualizing traffic in 3D/4D CAD models through two case studies on roadway construction projects – one in construction phase in Fort Worth, TX and the other in pre-construction phase in College Station, TX.One more case study for a detour scenario in Austin, TX is also described which is done to validate the traffic data generated from mesoscopic models. In each case study, a brief introduction is provided describing the project scope of work, estimated budget, duration of the project and the phase in which the project is modeled. Challenges specific to the project are also explained to justify why these case studies are selected for evaluation of traffic visualization models. Further, modeling process for the creation of geometry and traffic data is explained and justification for level of detail in the models is also explained. A detailed explanation is provided on the usage of models and the benefits that are identified.

The first case study, North Tarrant Express project, focuses on application of these models in construction phase and for TCP review of a project. The results of these visualizations showing their effectiveness in achieving the benefits are graphically shown at the end of case study based on the feedback received from traffic engineers and non-engineers. Second case study, FM 2154 and George Bush Drive Intersection, is an extension of the research findings put forth by a former member of the team. Extensive analysis was done on this project in evaluating use of 3D/4D models for traffic management planning (Goyat, 2012). In addition to that, traffic visualization is also added in the present case study to further reinforce the research analysis. The final case study, JW Marriott Austin, is a construction project being executed in downtown Austin, TX. The detour scenario resulted due to this construction is analyzed for data validation.

NORTH TARRANT EXPRESS PROJECT

This project is used as a case study to illustrate how traffic data can be incorporated into 3D/4D CAD models and the development of traffic data visualization in CAD models in conjunction with traffic control plans. These models will be used to explain the benefits of using traffic information to visually analyze the traffic control plans developed during traffic management planning and how the information can be communicated to various stakeholders (construction crew, motorists, local public and government agencies). This project serves as an example for applications of traffic data visualization in construction zones during the construction phase, besides its regular applications in 3-D visualization and construction sequencing with time.

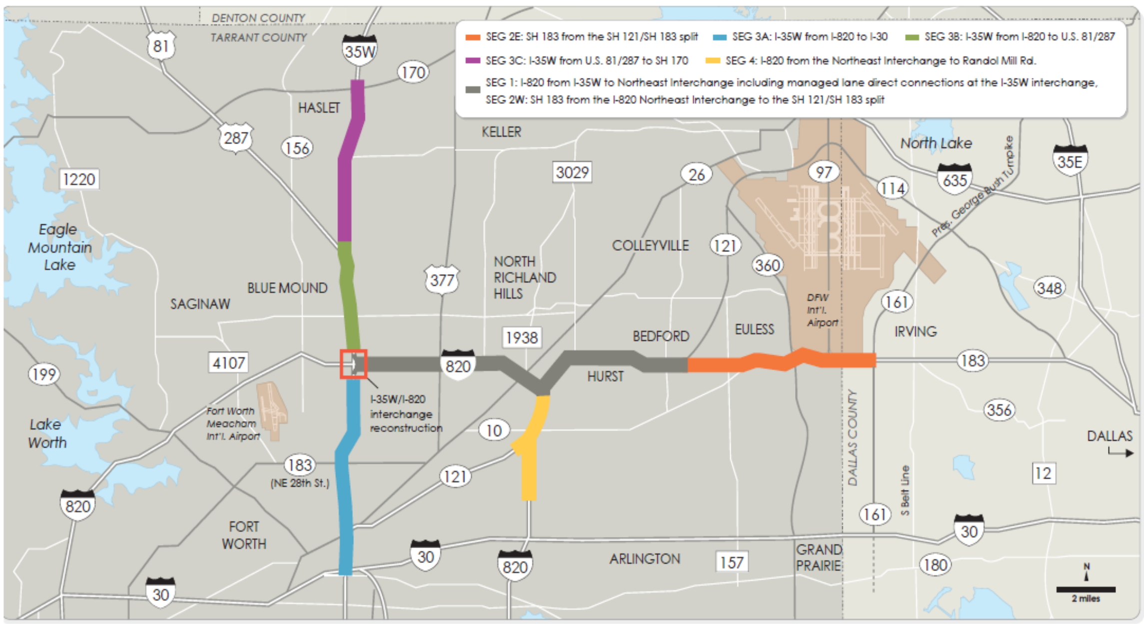
Overview

The North Tarrant Express (NTE) project consists of a series of major highway improvements to the Tarrant County's most congested highways Interstate 820 and State Highways 121 and 183 (Airport Freeway) corridors between I-35 West and Industrial Boulevard in North Tarrant County, Texas. The main aim of the NTE project is to improve mobility along the aforementioned freeways through construction of new managed lanes system. NTE provides eight to ten lanes on I-820 and SH 121/183. The project is being designed and built concurrently by NTE Mobility Partners (NTEMP) (TxDOT, 2012).

The salient features of this $ 2.5 Billion project are:

- Segment 1 (I-820 from I-35W to Northeast Interchange)
  – 6.4 miles
- Segment 2W (Northeast Interchange to FM 157/Industrial Boulevard)
  – 6.9 miles
- Complete reconstruction to upgrade existing general purpose lanes

- Improving and expanding frontage lanes to add capacity
- Two general purpose lanes and two managed lanes in median area
- Managed lanes featuring toll rates adjusted as traffic increases or decreases



SEG*	Roadway and Limits	Existing lanes (Each dir.)	Frontage lanes (Each dir.)	Configuration as proposed in Regional Mobility 2030 Plan**		
				General purpose lanes (Each dir.) ^^^	Managed lanes (toll) (Each dir.)	Frontage lanes (Each dir.)
2E	SH 183 from the SH 121/SH 183 split	3	2^	4	3	2^^
3A	I-35W from I-820 to I-30	2 - 3	2^	4	2	2^
3B	I-35W from I-820 to U.S. 81/287	2	2	4	2 - 3	2
3C	I-35W from U.S. 81/287 to SH 170	2	2	3	2	2
4	I-820 from the Northeast Interchange to Randol Mill Rd.	2 - 4	0	5 (SH 121N to SH 121S)	1 (SH 121N to SH 121S)	0

Figure 5.1 NTE projectmap(NTE, North Tarrant Express, 2012)

Challenges

The existing roadways currently handle up to 175,000 vehicles per day. Many parts of the project area in which NTE is being built are ranked among the 100 most congested roadways in Texas. This corridor is expected to be one of the fastest growing areas in Tarrant County with expected vehicles of 250,000 per day on I-820 corridors and

317,000 vehicles a day in SH 183 by the year 2030. Also, Dallas-Fort worth International Airport (DFW), the third busiest airport in the world, generates a huge amount of traffic in this region.

The above facts depict the importance of traffic management during construction phase of this project. The project is spread over a vast area, the construction activities not only affect the local community but also commuters along freeways due to partial lane closures, narrowing of open lanes, reduced stopping sight distance (SSD) due to obstructed views by construction equipment and congestion on roads.

Texas Department of Transportation (TxDOT) and the construction agency, NTE Mobility Partners are committed to keeping traffic moving safely during construction by installing signs along highways to inform drivers of closed ramps and lanes, detours or traffic switches. In addition to these efforts, communication of these changes prior to construction by leveraging the capabilities of 3D/4D CAD models to use traffic information from DTA models is expected to add great value to the public information part of traffic management planning.

Building 3D/4D CAD model

Scope of the model

The first step in building the 3-D model is assessing the project scope through review of plans provided by TxDOT. The length of the project being over 13 miles, it is divided into 2 segments (West segment–1 and East segment-2) with different lanes (managed, general purpose, frontage, ramps, cross roads and direct connectors) in westbound and eastbound directions. In order to capture the phasing and construction sequence of the project different lanes are given a color code for easy identification. Initially, the main intent of building the model was 4-D visualization of new construction for communication during public meetings with stakeholders and the public. Hence, only future conditions are modeled for the entire project because modeling of both existing and future conditions takes a considerable time without much added value. However, USGS data is used as a background when visualizing these models, to co-relate existing conditions for understanding the expansion of the lanes and the new ROW acquisition.

Terrain and context information

As mentioned in previous reports, adding terrain data to 3-D models improves visualization when compared to hanging objects in 3-D space. LIDAR data in .tin format was used to extract terrain information for the project area. Using Autodesk surface editing tools, better ways to optimize the information to fit into 3-D models were applied. The terrain information received is for existing conditions. Data was edited to incorporate changes in ground elevations, cuts and fills while accommodating new roads and ramps.

Construction sequencing visualization

Interim schedules from TxDOT monthly updates were used to visualize the construction by linking 3-D models with construction schedules in Autodesk Navisworks. Construction phasing plans provided by TxDOT helped delineate the schedule into different phases and figuring out the section wise construction of the project. 4-D animations are created to visualize the schedule and for public information during public meetings organized by TxDOT. Figure 5.3 shows one of the 4-D animations being displayed during a public meeting.

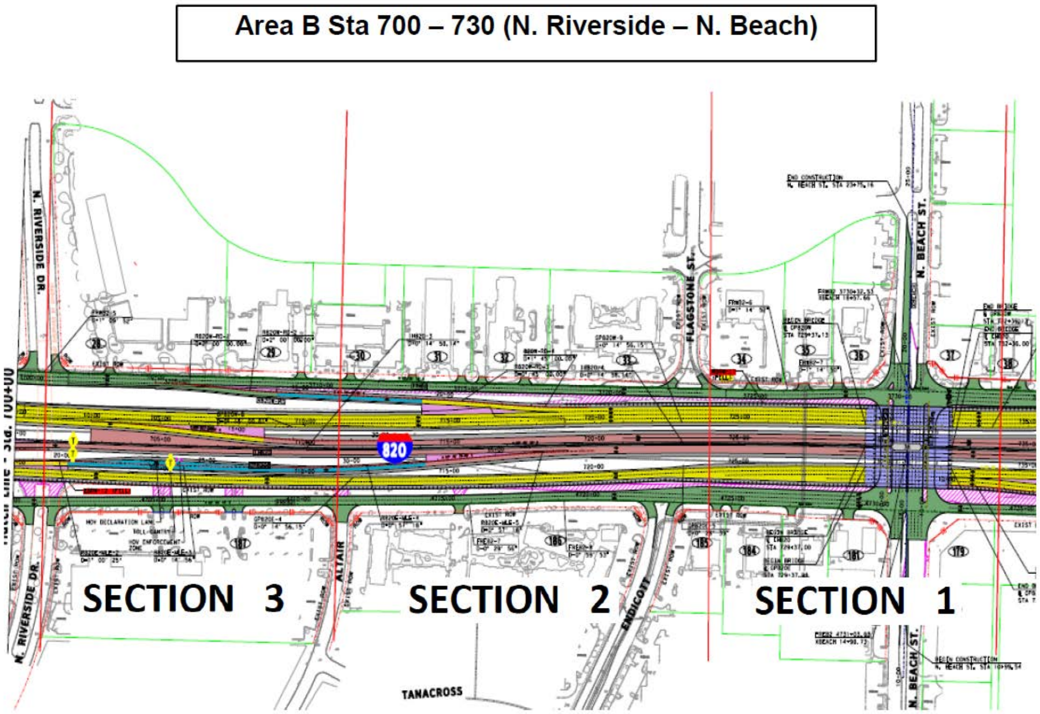


Figure 5.2 NTE project construction phasing plan

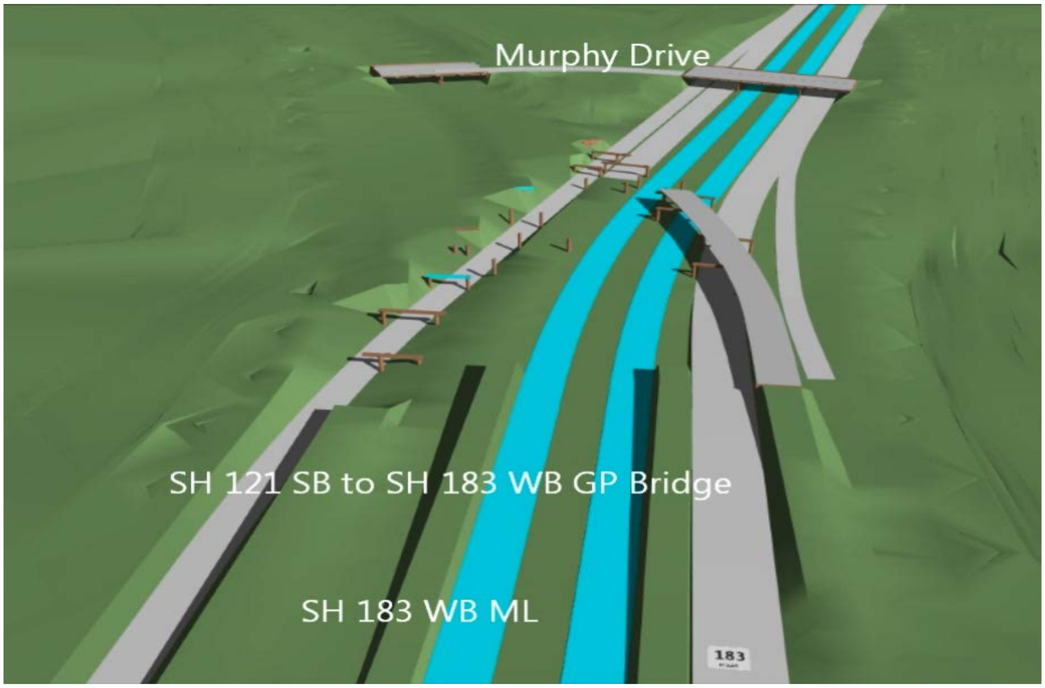


Figure 5.3 NTE project 4D CAD visualization

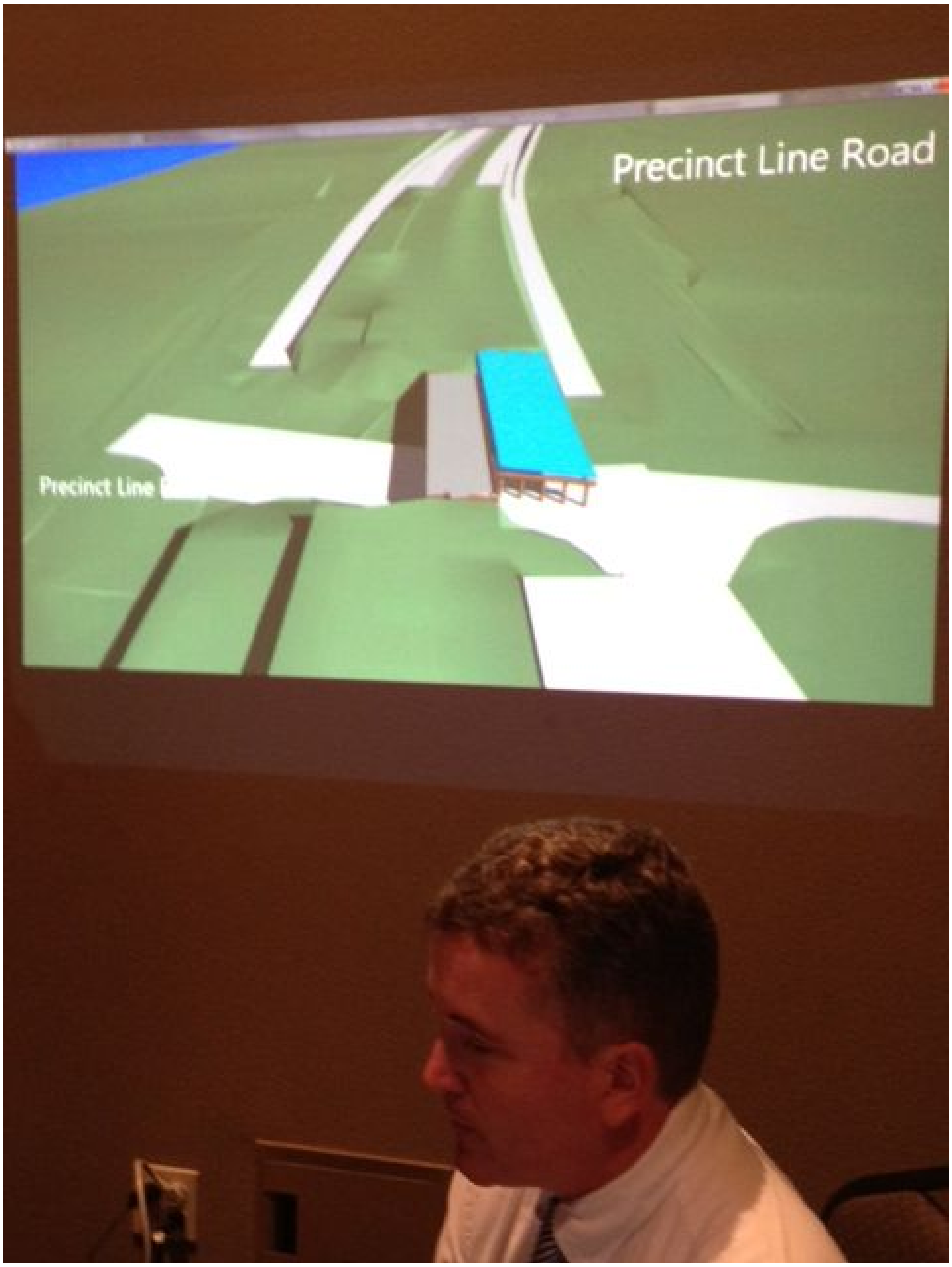


Figure 5.4 4D animations being displayed during TxDOT public meeting (NTE, 2012)

It was during public meetings that feedback was collected from local people and motorists who commute through the area regarding the inconvenience being faced due to construction of crossroads at intersections. Based on the information gathered, TxDOT public information officers concluded that construction around North Beach street intersection has been causing major impact on level of service offered to commuters travelling in the project area.

Figure 5.5 Public viewing 4D CAD animations during public meetings (NTE, 2012)

Also, advanced renderings of future conditions were displayed during public meetings to show how the project looks after completion. Vehicle rendering was also done to augment the virtual reality of these visualizations. Though the vehicle number, speeds, chainage and headway are not as per real conditions, the intent was to help thepublic to understand lane configurations, exit and entry ramps and cross street expansions. As a response to the renderings, simulation of real time traffic conditions during construction and TCP visualization were suggested. N.Beach street intersection was chosen for simulating traffic information into 3D/4D CAD models as analysis on this intersection can add public information value.

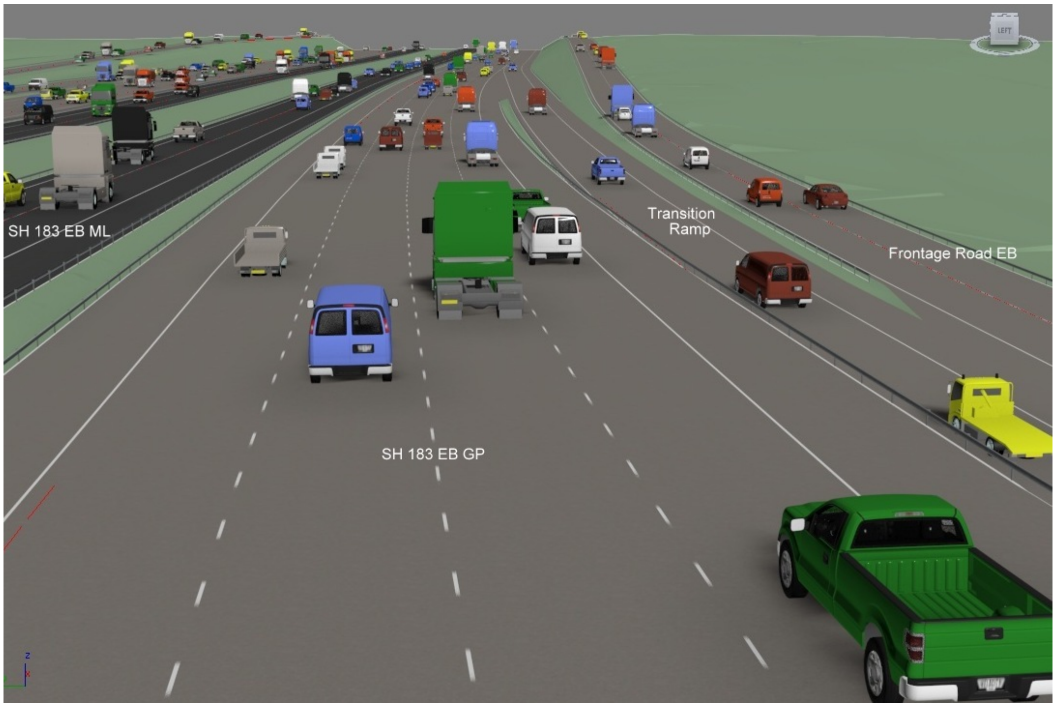


Figure 5.6 Virtual reality renderings of proposed project after construction

North Beach Intersection

N.Beach Intersection construction is a part of NTE project segment 1. It is located between chainage 730+00.00 and 732+00.00 of IH 820 in the perpendicular direction. Based on information from TxDOT officials, Beach Street is one of the busiest cross streets near IH35 W/IH820 interchange because of the residential housing in the vicinity and presence of many commercial businesses along the street. Also, construction near IH35W/IH820 (circled in red) resulted in commuters avoiding the interchange and usingN Beach (highlighted in black) to enter/exit IH 820 towards DFW (Dallas-Fort Worth International Airport).

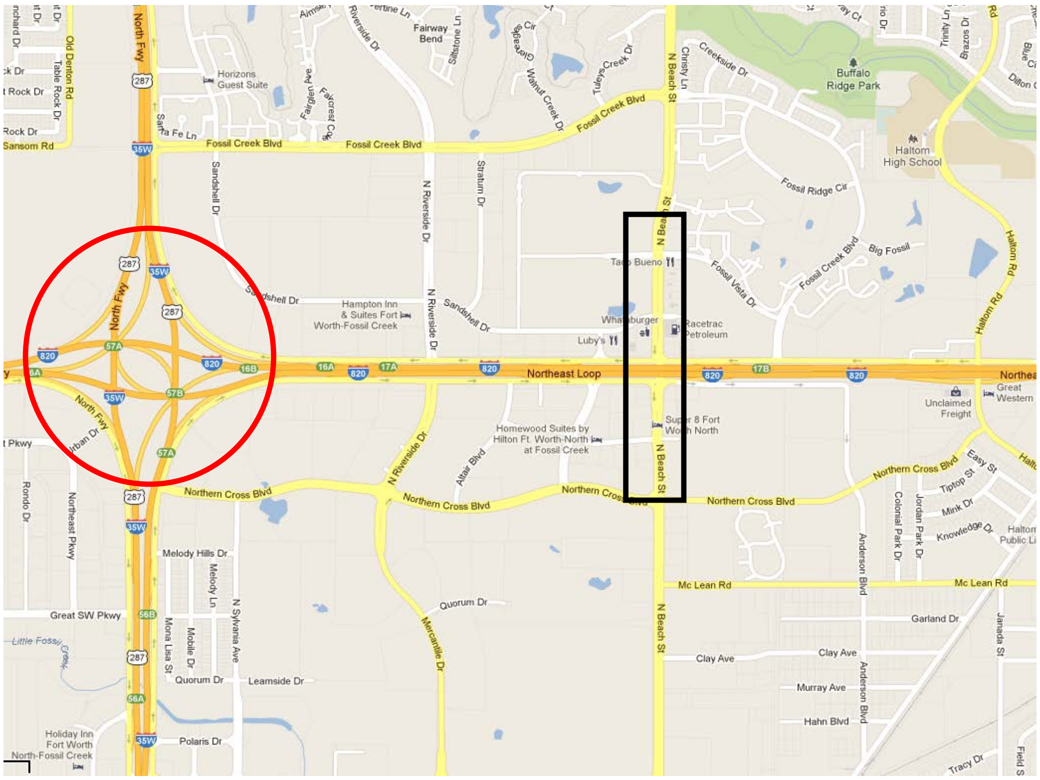


Figure 5.7 Google Maps® showing IH35/IH 820 intersection and N. Beach Street

Existing conditions

N. Beach intersection consists of 2 lanes each in Northbound and Southbound directions. It also has 1 turning movement for entry and exit on both Eastbound and Westbound Frontage roads. IH-820 runs perpendicularly to Beach Street on two grade separated bridges (West and East bound).

Figure 5.8 Google Maps® satellite view of existing N. Beach Street

Construction scope

The scope of construction around N.Beach street intersection involves:

1. Pavement laying and new configuration of existing lanes
2. Free U-turn movement from Eastbound frontage road to Westbound frontage road
3. Free U-turn movement from Westbound frontage road to Eastbound frontage road
4. Increasing number of lanes from 2 to 4 in both Northbound and Southbound directions under the IH820 bridges
5. Re-arrangement of road alignments to accommodate new IH-820 bridges

The scope of construction is derived from schematic plans of the project as shown in the figure 5.9

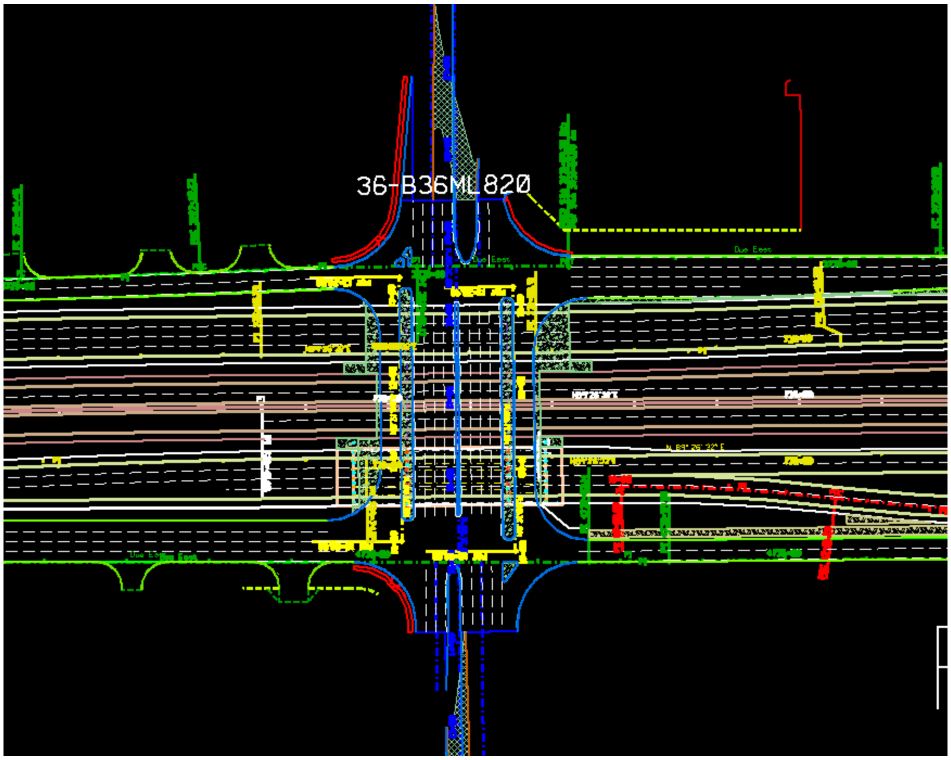


Figure 5.9 Proposed expansion of N. Beach street

Construction phasing

The construction schedule was analyzed to understand the phasing of N.Beach construction. However, the level of detail observed in the schedule was not comprehensive enough to be able to explain construction of new pavement and modification of the existing pavement through a 4-D simulation. 4-D simulation of the schedule activities was not very instrumental in conveying the construction phasing scenario and traffic de-touring to the public audience as less information on lane configuration changes was available.

Area XR0-B, PH 1, N. Beach Rd., Place Temp Erosion Control South	7/14/2011	7/15/2011	6/5/2013	6/6/2013
Pavement and Pvmt. Markings	10/17/2012	3/6/2013	10/17/2012	3/6/2013
Area XR0-B, N. Beach Rd., Place Flexible Base	10/17/2012	10/23/2012	10/17/2012	10/23/2012
Area XR0-B, N. Beach Rd., Place Curb & Gutter	10/24/2012	11/1/2012	10/24/2012	11/1/2012
Area XR0-B, N. Beach Rd., Place Flexible Base	10/31/2012	11/6/2012	10/31/2012	11/6/2012
Area XR0-B, N. Beach Rd., Place HMA Base	11/2/2012	11/5/2012	11/2/2012	11/5/2012
Area XR0-B, N. Beach Rd., SW Interim-Finish	11/6/2012	11/6/2012	11/6/2012	11/6/2012
Area XR0-B, N. Beach Rd., Place Curb & Gutter	11/7/2012	11/15/2012	11/7/2012	11/15/2012
Area XR0-B, N. Beach Rd., Place HMA Base	11/16/2012	11/19/2012	11/16/2012	11/19/2012
Area XR0-B, N. Beach Rd., NW Interim-Finish	11/20/2012	11/20/2012	11/20/2012	11/20/2012
Area XR0-B, N. Beach Rd., Place Flexible Base	12/21/2012	1/2/2013	12/21/2012	1/2/2013
Area XR0-B, N. Beach Rd., Place Curb & Gutter	1/3/2013	1/11/2013	1/3/2013	1/11/2013
Area XR0-B, N. Beach Rd., Place HMA Base	1/14/2013	1/15/2013	1/14/2013	1/15/2013
Area XR0-B, N. Beach Rd., SE Interim-Finish	1/16/2013	1/16/2013	1/16/2013	1/16/2013
Area XR0-B, N. Beach Rd., Place Flexible Base	1/17/2013	1/23/2013	1/17/2013	1/23/2013
Area XR0-B, N. Beach Rd., Place Curb & Gutter	1/24/2013	2/1/2013	1/24/2013	2/1/2013
Area XR0-B, N. Beach Rd., Place HMA Base	2/4/2013	2/5/2013	2/4/2013	2/5/2013
Area XR0-B, N. Beach Rd., NE Interim-Finish	2/6/2013	2/6/2013	2/6/2013	2/6/2013
Area XR0-B, N. Beach Rd. FF Start	2/6/2013	2/6/2013	2/6/2013	2/6/2013
Area XR0-B, N. Beach Rd., Place SMA Surface	2/7/2013	2/8/2013	2/7/2013	2/8/2013
Area XR0-B, N. Beach Rd., Place Sidewalks	2/7/2013	2/13/2013	2/7/2013	2/13/2013
Area XR0-B, N. Beach Rd., Install Perm Markings	2/11/2013	2/12/2013	2/11/2013	2/12/2013
Area XR0-B, N. Beach Rd. Finish	3/6/2013	3/6/2013	3/6/2013	3/6/2013
Earthwork	9/4/2012	1/16/2013	9/4/2012	1/16/2013
Area XR0-B, N. Beach Rd., SW Start	9/4/2012	9/4/2012	9/4/2012	9/4/2012
Area XR0-B, N. Beach Rd., NW Start	9/4/2012	9/4/2012	9/4/2012	9/4/2012
Area XR0-B, N. Beach Rd., Rem Conc Pavement	9/5/2012	9/11/2012	9/5/2012	9/11/2012
Area XR0-B, N. Beach Rd., Rem Conc Pavement	9/5/2012	9/11/2012	9/5/2012	9/11/2012
Area XR0-B, N. Beach Rd., Excavate Cut Areas	9/12/2012	9/25/2012	9/12/2012	9/25/2012
Area XR0-B, N. Beach Rd., Excavate Cut Areas	9/12/2012	9/25/2012	9/12/2012	9/25/2012
Area XR0-B, N. Beach Rd., Place Embankment	9/26/2012	10/9/2012	9/26/2012	10/9/2012
Area XR0-B, N. Beach Rd., Lime Treat Subgrade	10/10/2012	10/16/2012	10/10/2012	10/16/2012
Area XR0-B, N. Beach Rd., Place Embankment	10/10/2012	10/23/2012	10/10/2012	10/23/2012
Area XR0-B, N. Beach Rd., Lime Treat Subgrade	10/24/2012	10/30/2012	10/24/2012	10/30/2012
Area XR0-B, N. Beach Rd., SE Start	11/6/2012	11/6/2012	11/6/2012	11/6/2012
Area XR0-B, N. Beach Rd., Rem Conc Pavement	11/7/2012	11/13/2012	11/7/2012	11/13/2012

Figure 5.10 Schedule showing pavement construction of N. Beach street

The next step is to analyze Traffic Control Plans (TCP) for construction phasing and traffic handling in this intersection area during construction. TCPs in 2-D were analyzed to understand the phasing of the N Beach construction. Construction is executed in 4 phases as follows -

Phase 1-A:

Construction: Construction of U-turn pavements and Southbound N.Beach lanes

Traffic: Detour of traffic at Eastbound and Westbound frontage road intersections with existing N. Beach lanes

Phase 1-B:

Construction: Widening of existing pavements and new right turn movement on to Northbound Beach at Westbound frontage road intersection

Traffic: Detour of Northbound and Southbound Beach traffic to new lanes under IH820 bridges. Addition of a lane along Northbound Beach Street to accommodate a right turn at the intersection with the Eastbound frontage road.

Phase 1-C:

Construction: Patch construction on Northbound Beach lanes. New lane along Westbound frontage road at the intersection with N Beach street

Traffic: Reduction of the number of Northbound lanes to 2 from 3. Re-opening of a separate right turn lane to theEastbound frontage road. Also, right turn movement from the Westbound frontage road to Northbound Beach is re-opened.

Phase 1-D:

Construction: Median construction along North and Southbound Beach. Construction of 2 lanes along Southbound Beach.

Traffic: De-touring Northbound and Southbound traffic to U-turn movement lanes

2-D TCP schematics from which the above phasing was inferred are shown along with 3D models. Although 2-D TCP plans helped to decipher the construction scenario, it was difficult to assess the impact on traffic using this information. For example, reduction of westbound frontage lanes to 1 can have a big impact on traffic queuing at the intersection as both the left turning movements and straight movements are constrained to one lane. Compared to 2D paper plans, the construction phasing and traffic congestion can be easily represented through visualizing the impacted traffic conditions along with changed lane configurations.

Geometry models

As mentioned earlier, with changing geometry a single 4D model cannot be used for visualizing traffic, therefore multiple models had to be created for different construction stages. The intersection construction is divided into 4 phases. Hence 4 different models are created using updated TCP plans to represent open lanes during construction and the lanes that are built during that phase as follows:

Model 1 – Existing conditions (before start of construction)

Model 2 – Intersection during construction phase 1-A

Model 3 – Intersection during construction phase 1-B

Model 4 – Intersection during construction phase 1-C

Model 5 – Intersection during construction phase 1-D

Traffic information models

Fort Worth district traffic assignment model is used for generation of traffic information for this case study. The model is run in a program called VISTA. Peak hour volumes are considered for this analysis as peak hour volumes represent the worst case scenario in terms of congestion and inconvenience caused to motorists. Using a java script code and manual observations, the traffic volumes and turn movements for road network in this intersection are calculated and used as an input for microsimulation of existing lane geometry. But for traffic conditions representing ongoing construction, the traffic volumes extracted from the model may not be the same as real conditions since there are construction activities going on before and after the Beach intersection along IH 820, which might affect the amount of traffic at Beach. 2-D TCP documents were analyzed to identify activities that could impact traffic in this intersection while Beach Street is under construction. The activities that were identified are listed below according to the phase and stage in which they occur:

ADVANCE PACKAGE – 01

STAGE 2

- Shift eastbound and westbound traffic on GP lanes to shoulder and widened pavement
- Construct managed lane pavement from STA 737+00 to 810+00

ADVANCE PACKAGE-02

STAGE 1, STEP1

IH-820

- Construct Eastbound Frontage road
- Construct temporary widening along existing Eastbound 820 Mainlines
- Construct temporary EB entrance ramp from Beach
- Construct steps 1Aand 1B of Beach street staging
- Close Altair Blvd. and detour traffic. Construct Altair and reopen prior to closure of N.Riverside dr. and Endicott eve.
- Close Riverside and Endicott, and construct, prior to moving traffic onto new frontage road pavement
- Close EB Frontage Rd. east of Beach entrance ramp and Anderson street

STAGE 1, STEP 2

IH-820

- Divert traffic onto new EB frontage road pavement and construct remaining portion of frontage road
- Close existing 820 EB entrance ramp from Beach and open temporary ramp
- Permanently close existing EB exit ramp to Beach St

STAGE 2, STEP 1

IH-820

- Divert EB IH-820 and NB IH-35 connector traffic onto temporary widening. construct permanent EB general purpose (GP) lanes and EB GP bridge at Beach

- Construct temporary widening, west of IH 35W connector, along existing EB 820 Mainlanes and temporary detour pavement, east of beach, from proposed EB GP lanes to existing EB 820.

STAGE 2, STEP 2

IH-820

- Divert EB IH-820 and IH-35W NB connector traffic onto new GP lanes and construct remaining portions of permanent pavement

ADVANCE PACKAGE - 03

No relevant activities

ADVANCE PACKAGE – 04

PHASE 4B

STAGE 1, STEP 0

- Construct temporary widening of WB frontage road

STAGE1, STEP1

- Begin construction of proposed WB Frontage road from FRWB2 3662+00 to 3762+00
- Construct temporary WB detour pavement at approximate FRWB2 STA 3760+00
- Construct temporary widening on the WB frontage road from Haltom Rd to FRWB2 3780+00
- Close flagstone street detouring traffic to N.Riverside drive
- Begin Beach street phasing, Fossil Creek Blvd phasing and N.Riverside Drive phasing

STAGE 2, STEP1

- Shift traffic onto proposed WB frontage Road
- Construct temporary detour pavement from existing WB mainlanes to existing WB frontage road at IH 820 Sta 735+00

- Construct temporary detour pavement from existing EB mainlanes to existing WB mainlanes to IH 820 Sta 690+00
- Complete construction of frontage road from FRWB2 Sta 3693+00 to Beach St
- Construct WB exit ramp to Fossil Creek Blvd and begin WB General Purpose lane construction from IH 820 709+00 to Sta 766+00
- Construct temporary detour pavement from WB proposed General Purpose Lanes to existing WB mainlanes to IH 820 Sta 750+00

STAGE 2, STEP 1A

- Close N. Riverside Drive and detour traffic to Flagstone Street
- Shift WB Frontage road traffic at N. Riverside Drive and complete construction of the WB frontage road and intersecting street

STAGE 2, STEP 2

- Complete WB frontage road construction
- Shift WB mainlane traffic from existing WB mainlanes to detours constructed in Stage 2 Step 1
- Continue construction of WB General Purpose lanes from GP820W 682+00 to Sta 728+00

STAGE 3, STEP 1

- Shift WB mainlane traffic to proposed WB General Lanes
- Complete construction of WB Managed Lanes to IH 820 737+00
- Complete construction of Beach Street

Among these construction activities, it was observed that the IH 820 mainlanes do not have considerable effect on Beach intersection traffic as mainlanes have full capacity (2 lanes each west and east bound) using temporary pavements. But construction on frontage roads, permanent closing of old ramps; closing/opening of temporary ramps and opening of new proposed ramps did have an effect on traffic volumes entering or exiting the Beach intersection.

During each phase of Beach construction, changes in vehicle flows caused due to partial lane closures and ramp addition/closure was considered before running the microsimulation. Some of the changes observed were due to narrowing of the westbound frontage road between Haltom and Beach streets and also the addition of a new exit ramp from the mainlanes to the westbound frontage road.

Route attributes are assessed using as-built drawings and still imagery stored in Google maps. Signal control timings at controlled intersections are decoded from construction TCP documents. Based on general traffic rules, stop and yield preferences are assigned to vehicles travelling in particular lanes with conflict zones. Models are run with different ‘seed’ numbers to check robustness of the analysis. However, aggregate values of flows and turning movements from a set of simulations require further analysis. Similar to geometry models, 5 different microsimulation models are developed for existing conditions and phases A to D.

Combining geometry and traffic models

Geometry from Civil3D and microsimulation traffic information from VISSIM are combined together in 3ds Max. As software programs used in the process convert the geometry into their inherent local co-ordinate system, conversion of co-ordinate systems was taken into consideration and accordingly data (geometry and traffic) were shifted to align them together in 3dsMax. All vehicles are imported as cuboidal blocks to a plane surface though realistically, pavements upon which vehicles travel will have different elevations. In order to make the vehicles look more realistic, commonly used cars are used to replace these blocks adding more meaning to the visualization. Also, the vehicles are attached to pavements beneath them to ensure high-quality and more realistic visuals.

Visualization of construction phasing

Existing conditions:

The figure 5.12 shows the Beach street intersection before the start of construction with two fully open lanes on north & south bound on the Beach streets as well as eastbound frontage and west bound frontage roads.

Figure 5.11 Existing conditions of N. Beach Street

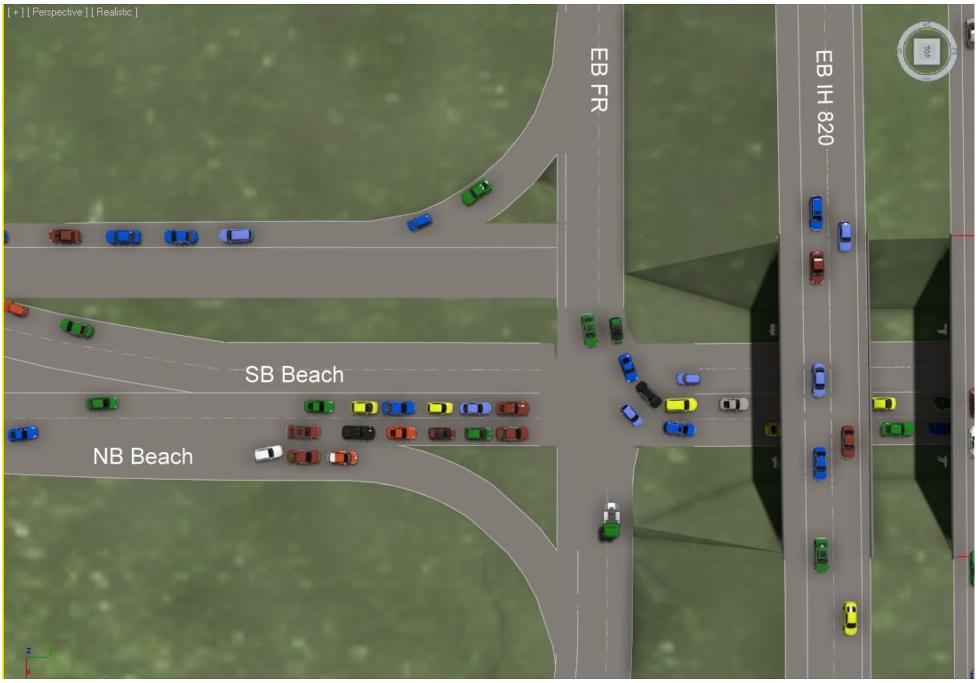


Figure 5.12 South side of N. Beach intersection

Figure 5.13 North side of N. Beach intersection

From figure 5.14 it can be inferred that queues are considerably bigger at signals. Congestion in existing conditions has made traffic analysis very crucial for this intersection during construction. Reasons for vehicle queues can be attributed to exit ramps on IH 820 on both east and west bound mainlanes before this intersection.

Beach street construction

As per the latest updated interim schedule, Beach Street pavement construction is scheduled after the existing bridges are demolished and new bridges are constructed along IH 820 with mainline traffic shifted to permanent managed lanes and temporary pavements.

Phase 1-A

During phase 1-A, little change in traffic patterns is observed to the south of the Beach intersection i.e., on the EB frontage side except for a shift of lanes to further south along the newly built EB frontage road. But, on the north side of the intersection, the WB frontage road is narrowed to 2 lanes from 3 lanes as in existing conditions. This increased queuing along the WB frontage road is shown in figures 5.15-5.19.

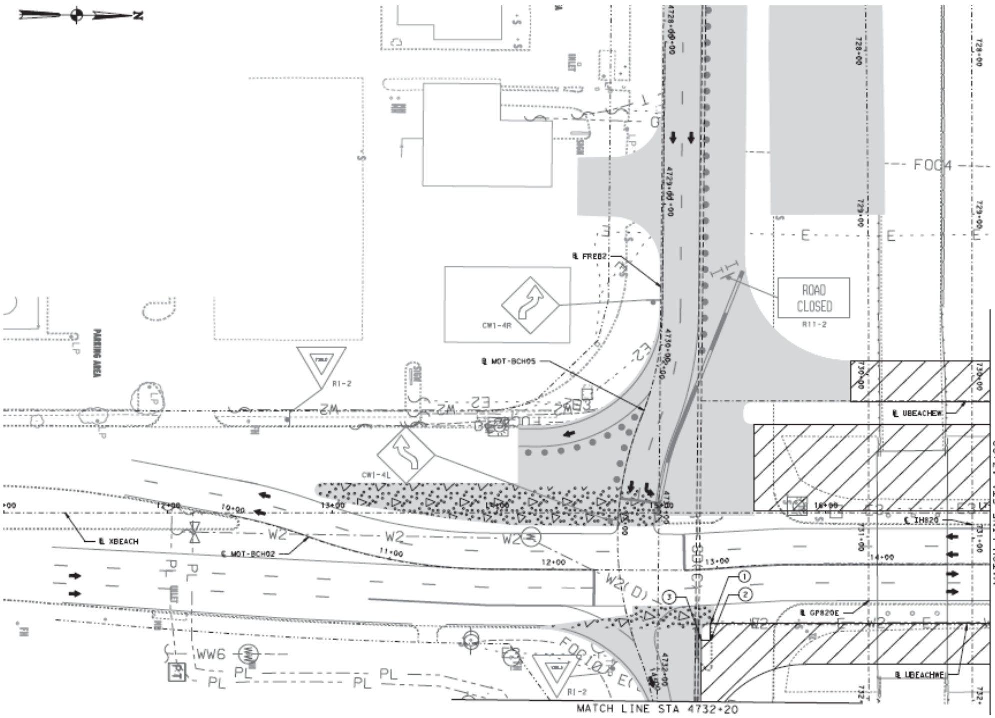


Figure 5.14 Phase 1-A – South side of N. Beach intersection in TCP

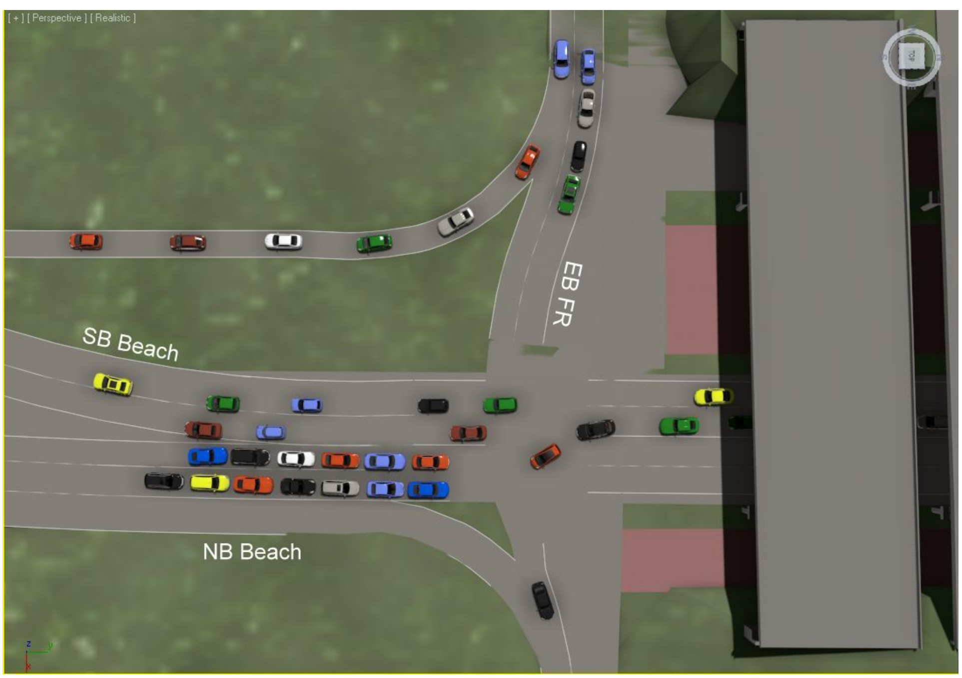


Figure 5.15 Phase 1-A – South side of N. Beach intersection in 3D model

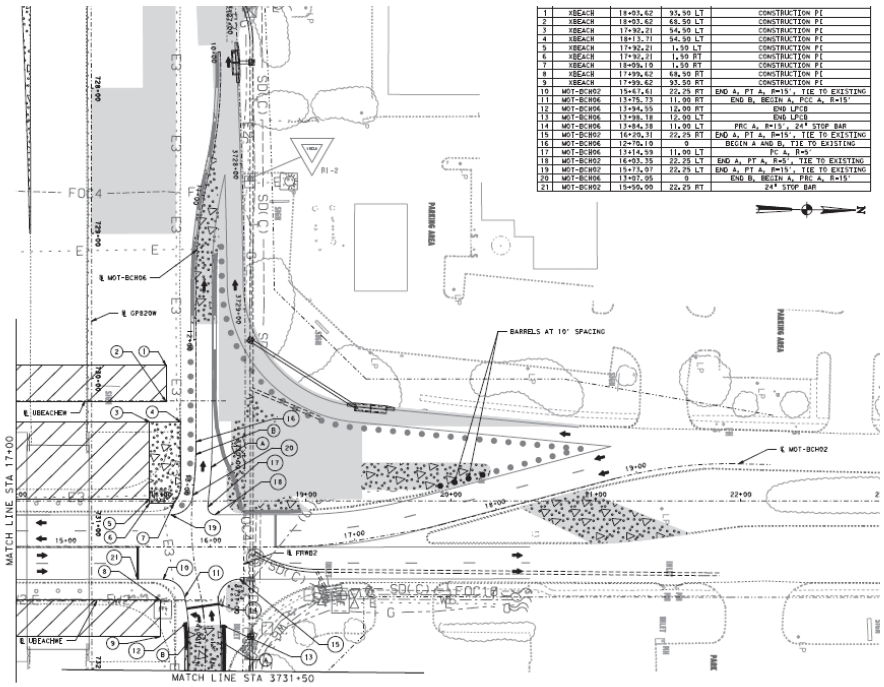


Figure 5.16 Phase 1-A – North side of N. Beach intersection in TCP

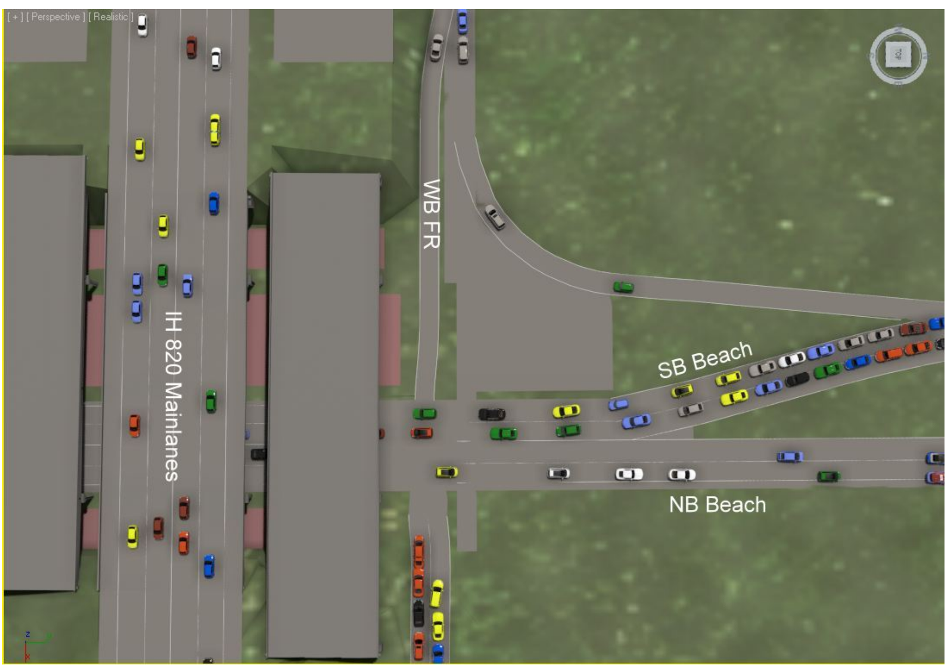


Figure 5.17 Phase 1-A – North side of N. Beach intersection in 3D model

Figure 5.18 Phase 1- A – Queuing on south bound N. Beach Street in 3D model

Phase 1-B:

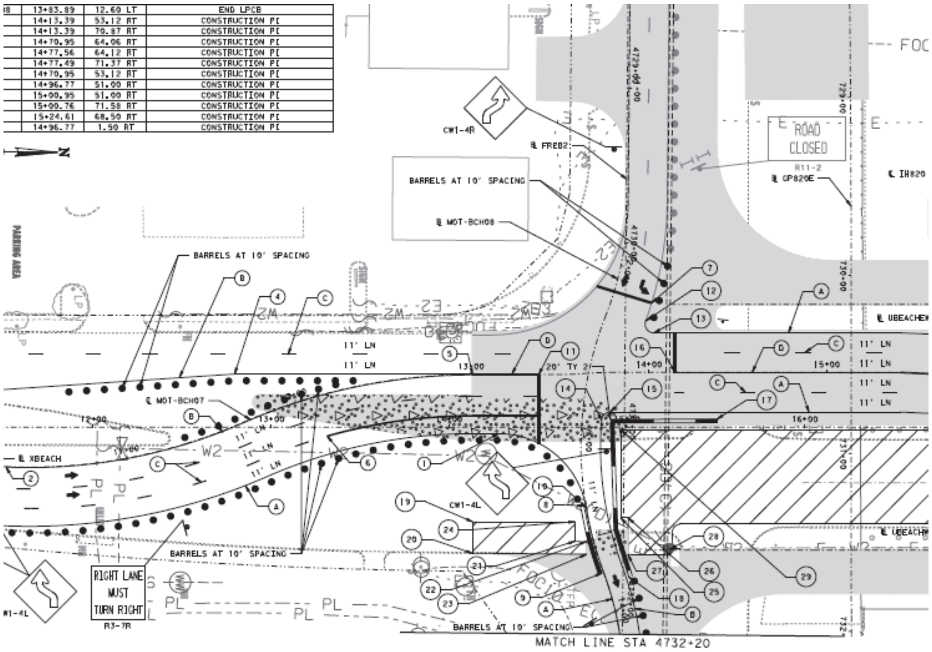


Figure 5.19 Phase 1-B – South side of N. Beach intersection in TCP

Figure 5.20 Phase 1-B – South side of N. Beach intersection in 3D model

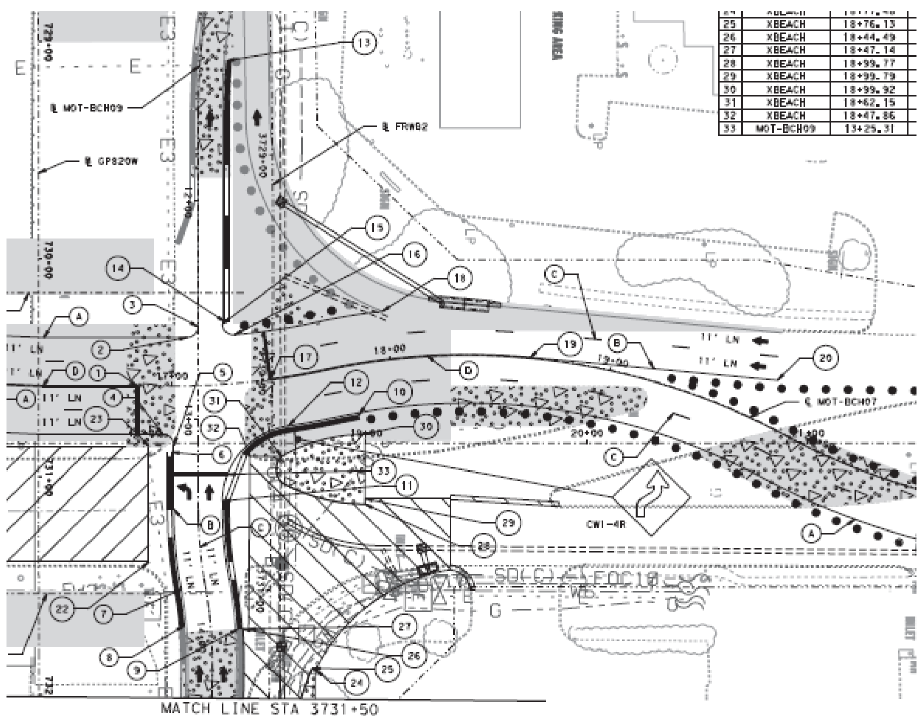


Figure 5.21 Phase 1-B – North side of N. Beach intersection in TCP

Figure 5.22 Phase 1-B – North side of N. Beach intersection in 3D model

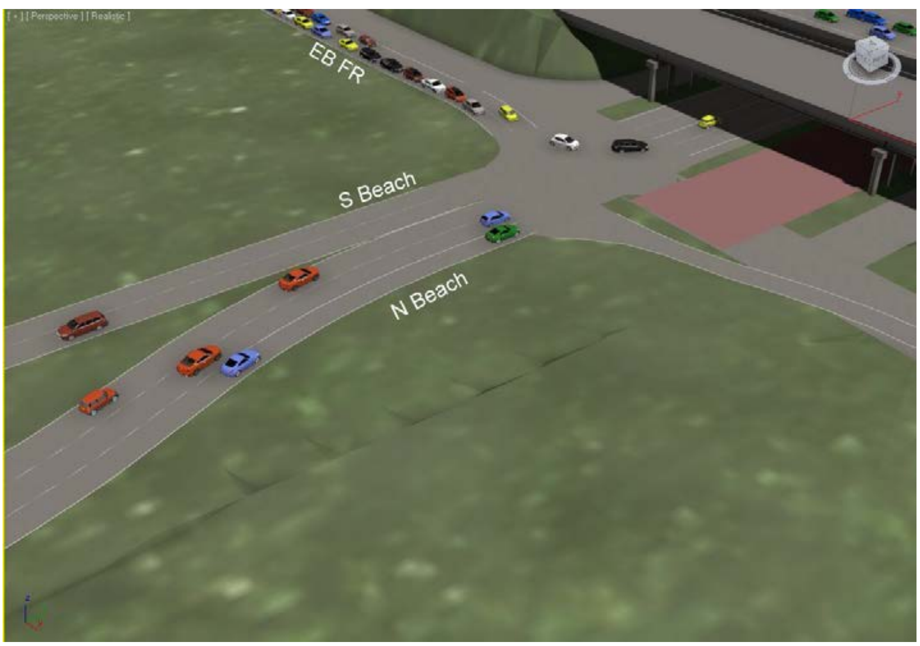


Figure 5.23 Phase 1-B – Queuing on south side of N.Beach intersection in 3D model

In phase 1-B, traffic volume on the EB frontage road is reduced due to permanent closure of the exit ramp from IH 820 prior to Beach Street. Also, merging of the right turn lane with through lanes along NB Beach has reduced traffic congestion in that direction. Open lanes along Beach Street are shifted west to facilitate paving of existing Beach lanes. Whereas on the other side of the intersection, traffic congestion on WB frontage road increased due to opening of a temporary pavement from IH 820 mainlines onto the frontage road. Also, removal of the separate right turn lane onto the WB frontage road also increased congestion along SB Beach Street.

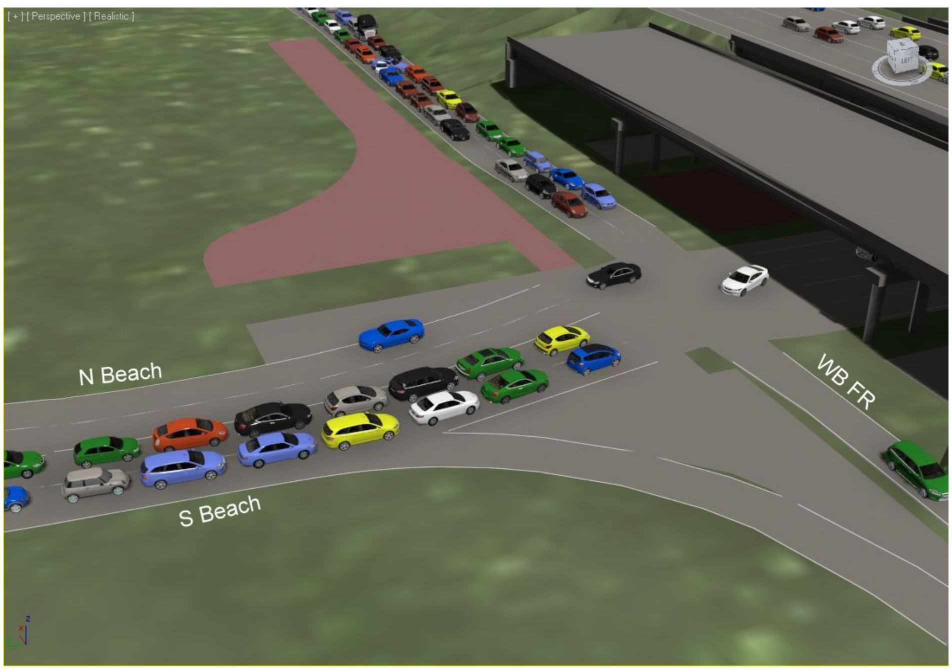


Figure 5.24 Phase 1-B – Queuing on north side of N. Beach intersection in 3D model

Phase 1-C:

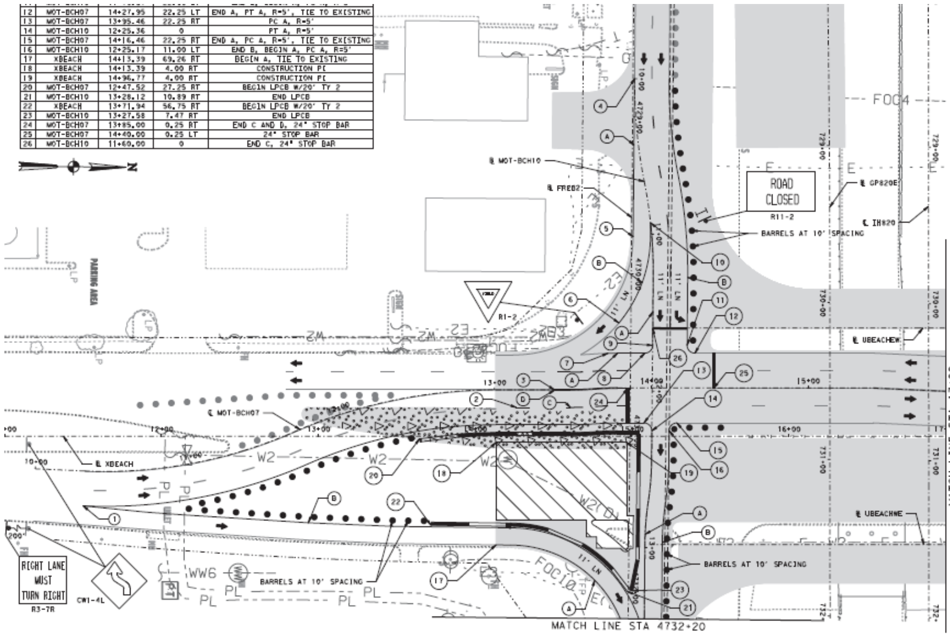


Figure 5.25 Phase 1-C – South side of N. Beach intersection in TCP

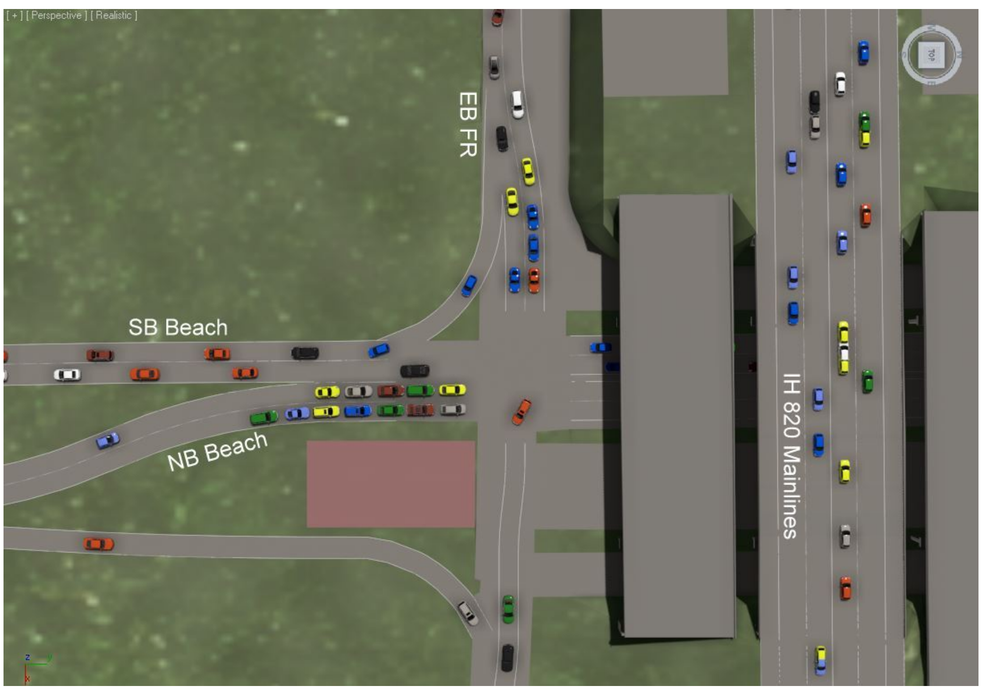


Figure 5.26 Phase 1-C – South side of N. Beach intersection in 3D model

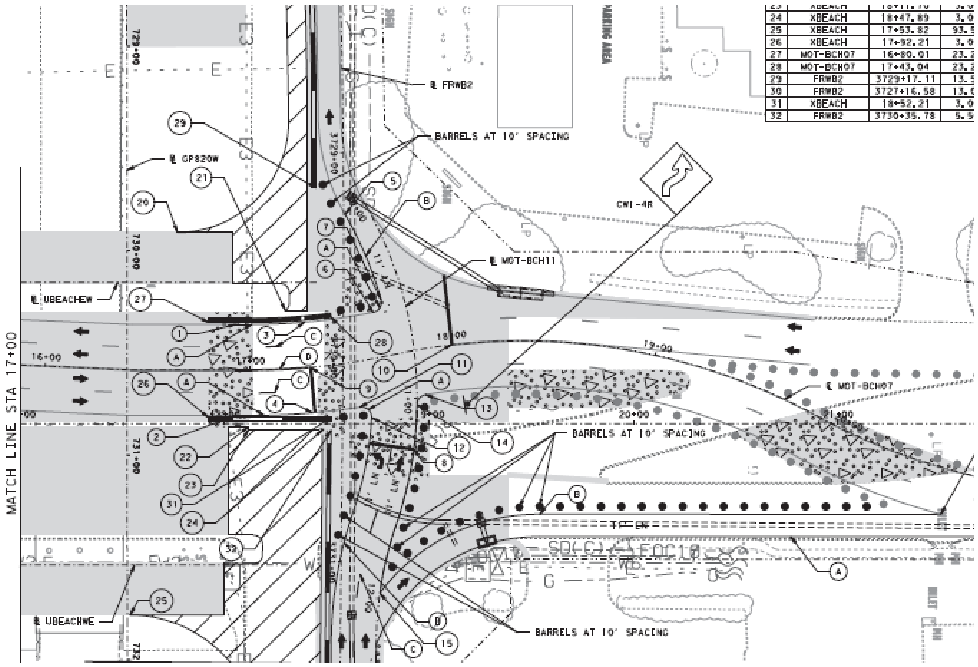


Figure 5.27 Phase 1-C – North side of N. Beach intersection in TCP

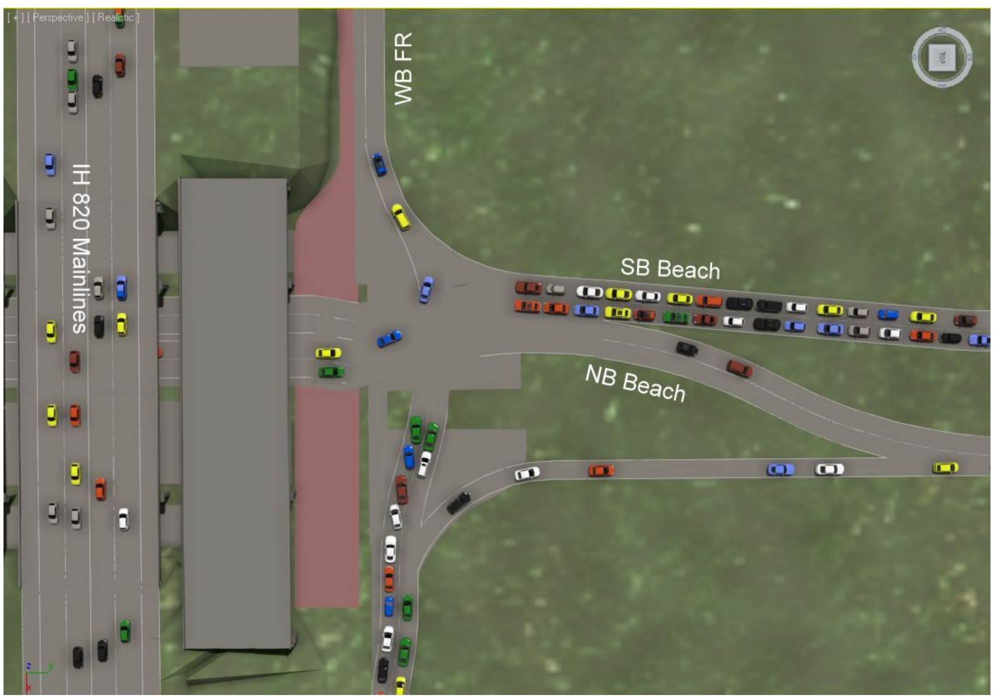


Figure 5.28 Phase 1-C – North side of N. Beach intersection in 3D model

No major changes in traffic are observed during this phase. But there are shifts of lanes on both sides of the intersection. The separate right turn movement is re-opened to EB frontage road from NB Beach Street. Also, open WB frontage lanes are shifted north for paving of the existing lanes.

Phase 1-D:

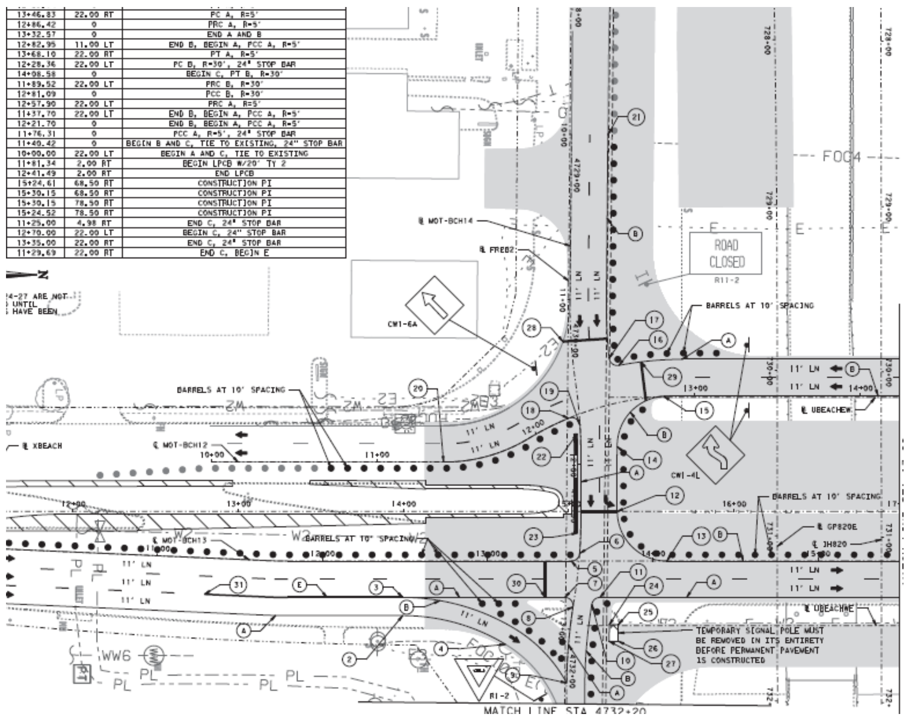


Figure 5.29 Phase 1-D – South side of N. Beach intersection in TCP

Figure 5.30 Phase 1-D – South side of N. Beach intersection 3D model

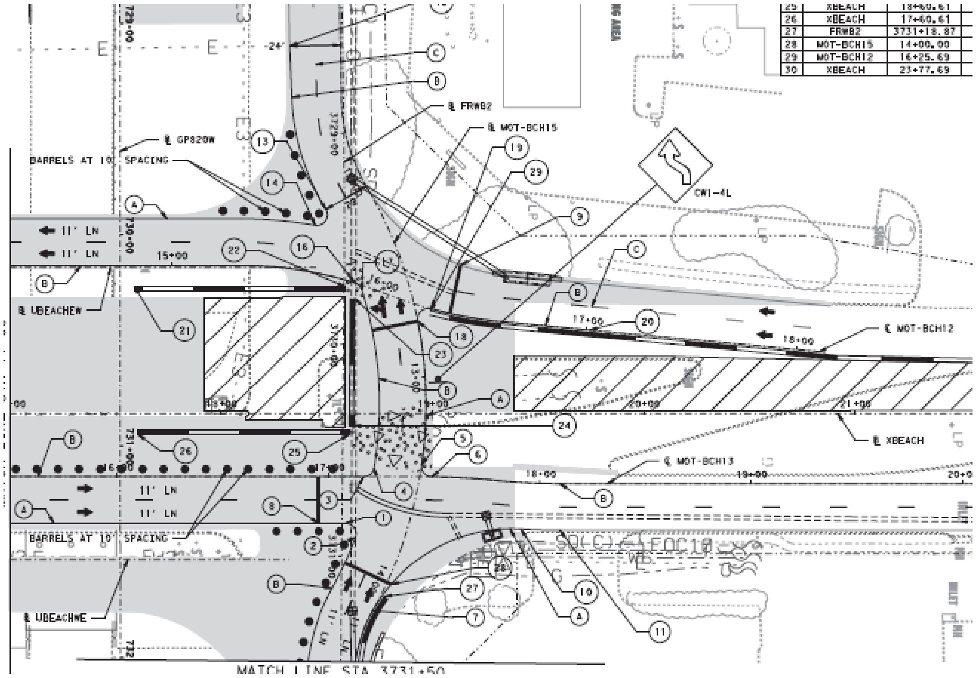


Figure 5.31 Phase 1-D – North side of N. Beach intersection in TCP

Figure 5.32 Phase 1-D – North side of N. Beach intersection in 3D model

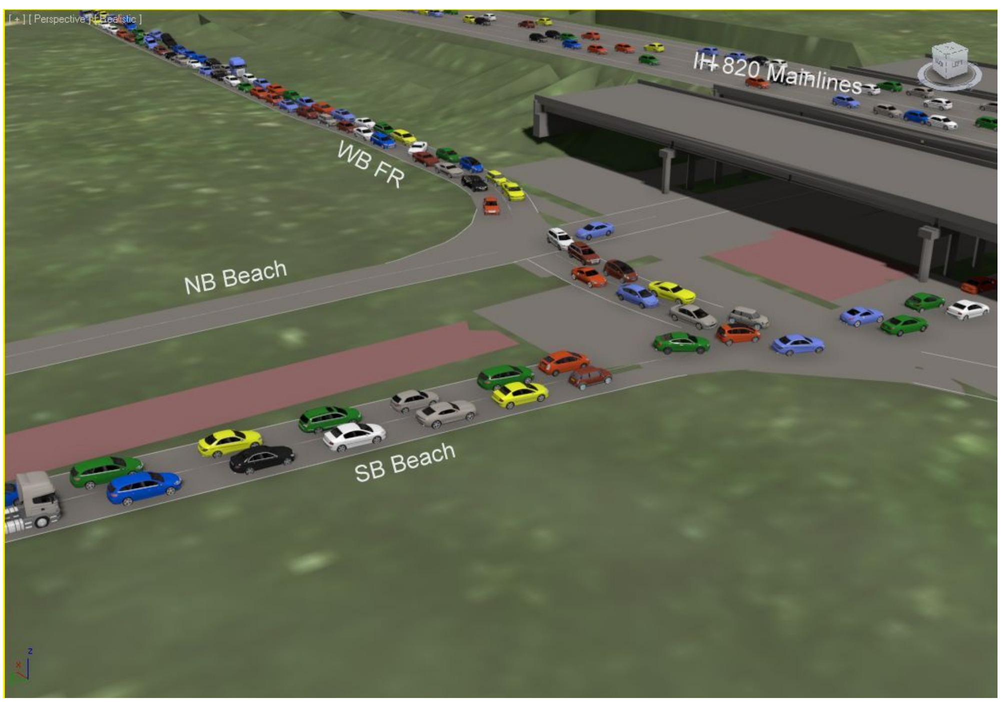


Figure 5.33 Phase 1-D – Queuing on north side of N. Beach intersection in 3D model

It is observed that queuing is long on the north side of N.Beach intersection along the westbound frontage road as shown in figure 5.34, due to addition of one more signal before turning on to South Beach Street. On reviewing the TCP for this phase, it is suggested that one more lane can be open on the frontage road to facilitate free movement of traffic

Using the models:

The main objective of developing these models is to increase the level of understanding of construction phasing and thereby enhance communication across stakeholders including TMP planners, the public and motorists. Addition of traffic to 3-D models moves virtual modeling a step closer to reality as both construction and traffic parameters can both be analyzed on a single platform instead of moving back and forth between 2-D plans and 2-D traffic microsimulation visuals.

These models were displayed to traffic engineers as well as other officials of TxDOT and researchers of the Center for Transportation Research (CTR) during an annual symposium event to collect feedback through interviews on how effective these models are in conveying TCP information and their application to DOT projects. The processes of acquiring traffic information, basis for geometry modeling from TCPs and the integration process were explained. Animations showing traffic flow during each construction phase were run and a small questionnaire was given to each participant at the end. Having explained the integration process and demonstrated the capabilities of these models, each participant was asked how they could use this tool in their daily job. Among the 15 participants, most of them concluded that these models can be definitely useful in more than one phase of a project, provided the constraints of time and level of detail are met as per project’s requirement. Also, traffic engineers explained many situations they faced when managing their regular projects where traffic management in construction zones become very critical and opined that availability of such a pro-active tool can reduce impacts on construction.

The interviews are summarized as follows:

Applicability of these models based on project phase is shown in figure 5.35. As per the interviews, 60% agree that 3-D models with traffic information can be used in the conceptual design phase of a transportation project. Similarly, 20%, 80% and 87% agree that the models can be used for project design, TMP and construction phases respectively.

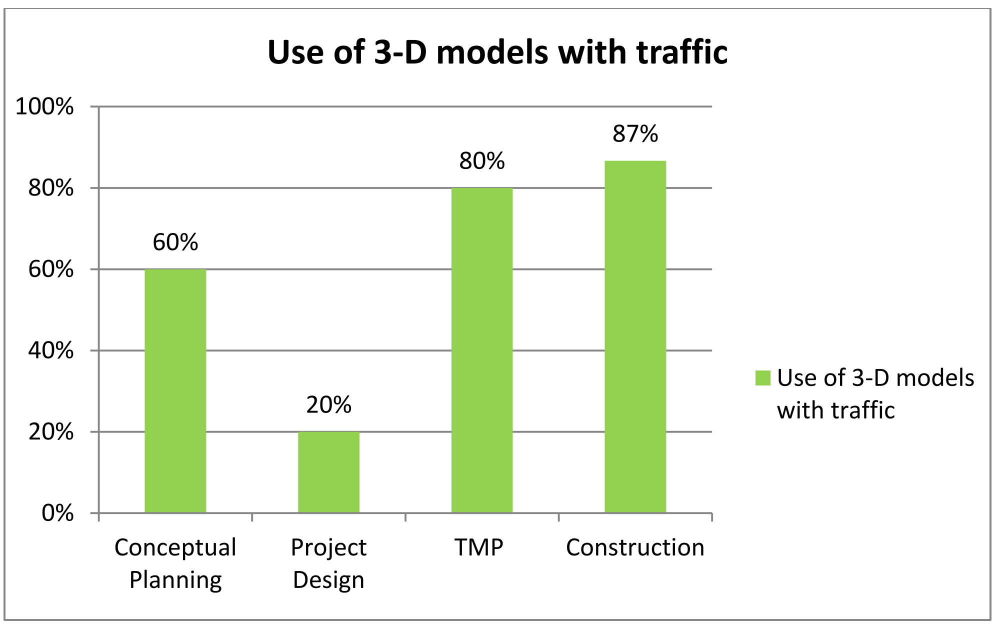


Figure 5.34 Bar chart showing use of 3-D models with traffic in various phases of project

Further during each of the above mentioned phases, specific areas of application were sought and the opinion based results are explained in following figures:

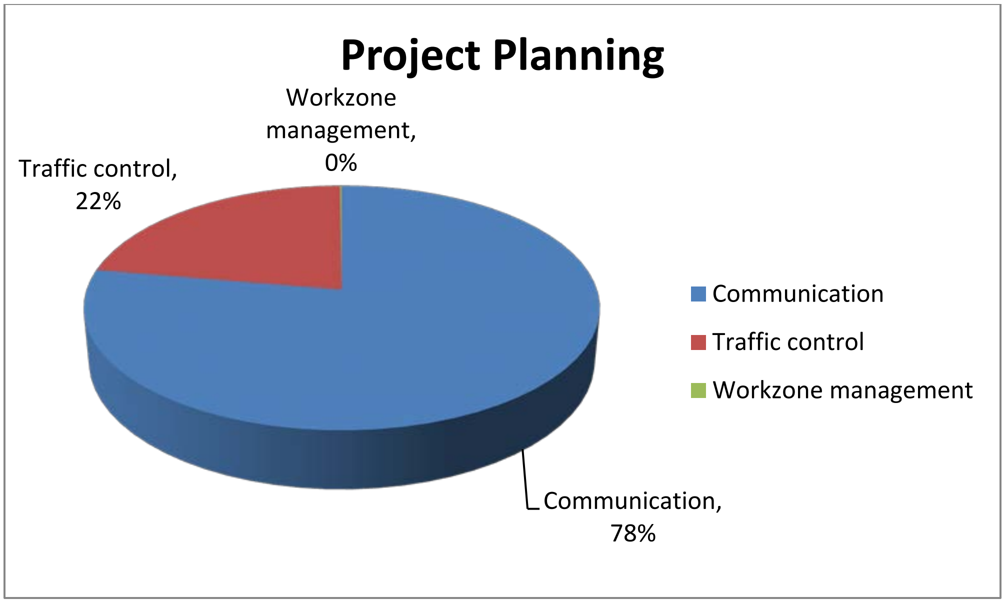


Figure 5.35 Pie chart showing use of 3D models with traffic in project planning phase

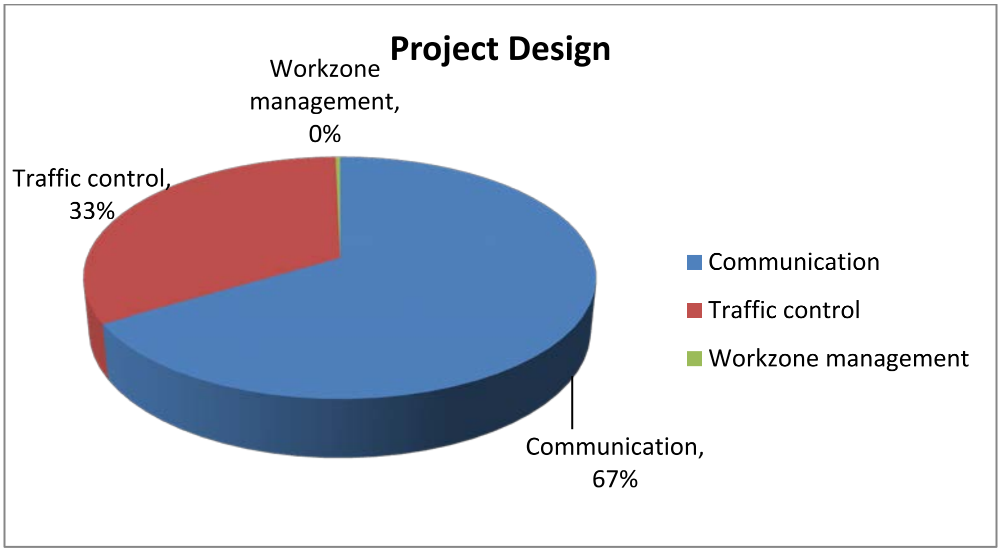


Figure 5.36 Pie chart showing use of 3D models with traffic in project design phase

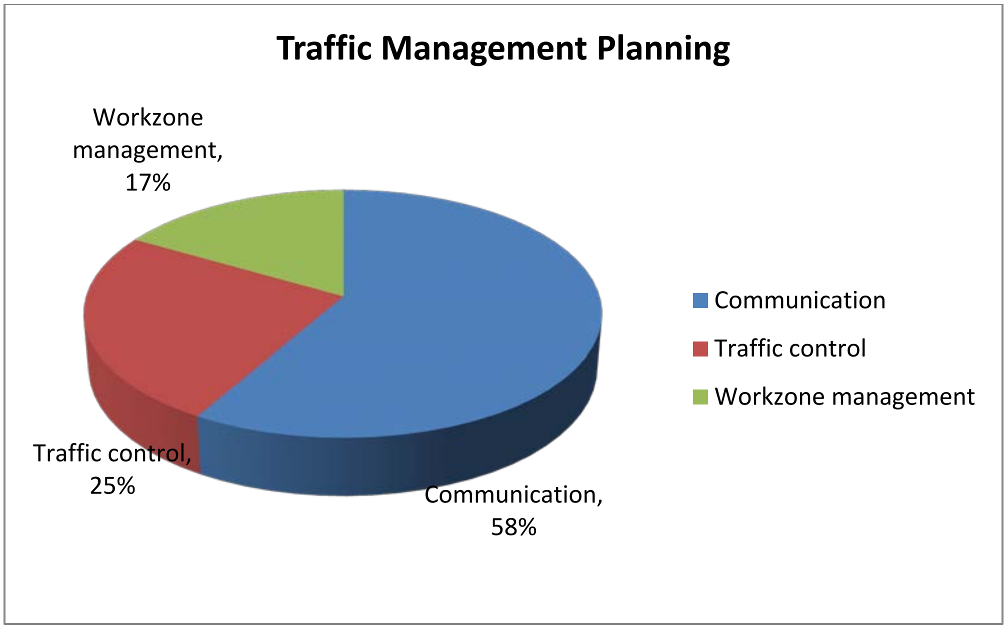


Figure 5.37 Pie chart showing use of 3D models with traffic in TMP phase

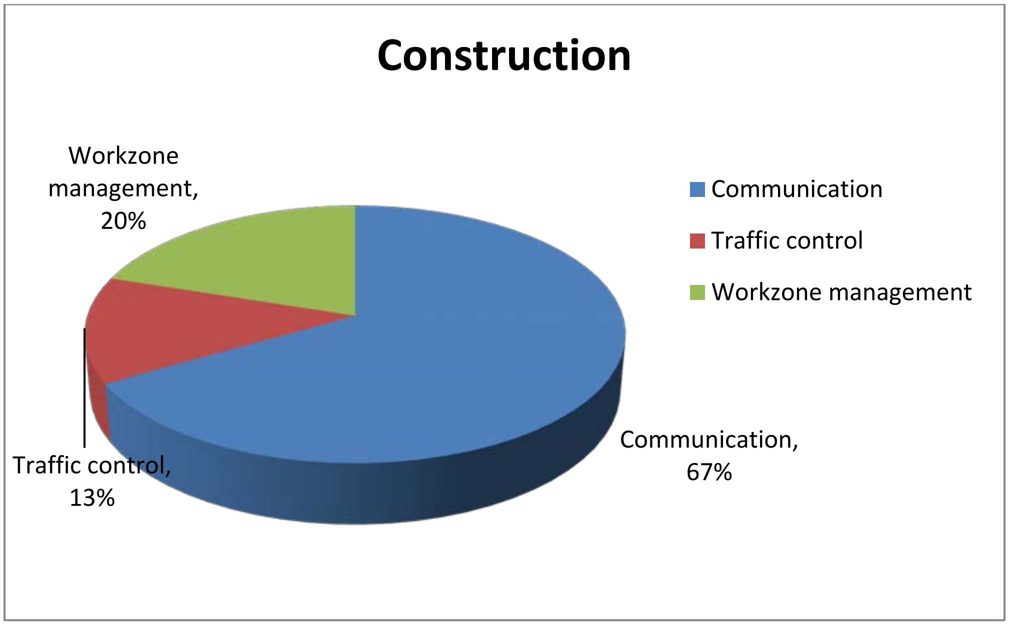


Figure 5.38 Pie chart showing use of 3D models with traffic in construction phase

Figure 5.39 indicates 67% of the participants agree that during construction these models can be used for communication across various stakeholders. Similarly, 13% agree that these can be used for traffic control and 20% for workzone management.

The areas of application of these models are:

Construction phasing visualization – The models facilitated accurate representation of TCP plans describing how the intersection will look while it is being constructed in phases. As the intersection is scheduled to be constructed in a span of 19 weeks and the intersection is one of the busiest along IH 820, it is definitely useful to the local businesses and residents to understand the phasing and traffic patterns. They can focus on discussing their concerns with DOT officials and builders, more easily than with separate traffic and geometry visualization.

Public information – Level of service is reduced during construction of most of the intersections. The observations (increased congestion, changes in lane configurations) made earlier in the visualization section can be justified and the reasons for lane detours, closures and shifts can be explained to the public. This helps in receiving public approval prior to construction and thereby reduces the chances of construction delays or design changes as the communication is done pro-actively.

Rapid TCP analysis – During TCP design, parametric study can be done on various alternatives under consideration and their performance can be checked immediately. During project execution, any changes in the TCPs can be immediately visualized. Construction schedule slippage might result in excess or reduced stretch of pavement for traffic movement. TCP at any point of interest can be optimized by visualizing as-built geometry up to that point of time from 4-D simulation.

Stakeholder inputs – Inputs from all stakeholders is important for proper project execution. One area where constructor/builder inputs are very crucial is usage of traffic control devices/barricades and space tolerances in compact work zones like intersections with open traffic. Even in design-build contracts, the TCP design team can take input from construction teams regarding the constructability on site using the proposed designs. 3D Models with traffic act as an efficient tool for virtually re-creating similar conditions and designs can be adjusted for better construction efficiency.

City operations – In DOT projects, generally frontage road construction is a part of main lane construction or expansion projects. One area where effective communication is very crucial is construction locations where a frontage road intersects a city street. City streets and signals are managed by city authorities. Continuous information flow is necessary between the project developer and city authorities to handle intersection signal operations and detours. Since microsimulation can effectively capture vehicle behavior and movements at intersections, 3D models with traffic data can be used as a medium of issue resolution with city authorities in a much better way than 2D TCP plans.

Observations

CAD models with traffic data proved instrumental in addressing the challenge areas that are identified in literature review. The results from interviews shown in figures 5.34 to 5.38 in this case study reinforce that the anticipated benefits of phasing and TCP communication can be achieved by using these models. To summarize the results, it can be concluded that these models can be used for communication and traffic control reviews in all phases of a project and they can also be used for work zone management in construction phase.

In the present case study for the Beach Street intersection, it is observed that the congestion on the westbound frontage road is much higher when compared to that on the Beach Street and the eastbound frontage road. Using these visualizations, the understanding of construction impact on traffic operations due to the partial lane closures is greatly enhanced than reviewing 2D TCP plans or 4D construction animations. This can be a very effective tool for the traffic engineers to oversee traffic operations during construction.Moreover, the ability of these models to integrate different file types from different programs and to export results in a variety of formats like videos, rendered images can greatly help in communicating the project information across different platforms viz., project meetings, open house public meetings, project websites and social media.These features enable the models to be used by both traffic engineers and non-engineers.

The current method of realistic traffic visualization takes considerable time to produce the desired results. Accuracy of inputs and level of detail are the two main factors that can affect the output of these models. Discussion on improvement for current method is mentioned in chapter 6.

FM 2347 GEORGE BUSH INTERCHANGE PROJECT

The following project demonstrates usefulness of traffic visualization in 3-D models during the project TMP planning phase. This project was extensively analyzed to explain how 3D/4D CAD models can be used in conjunction with traffic management planning to develop an integrated framework for developers to further review and communicate the project strategies to stakeholders by former member of the team, Jean Goyat in (Goyat, 2012) as a part of his Master's thesis. As the next step, effectiveness of traffic integrated 3D models to add further value to TMP planning is explored in this case study.

Overview

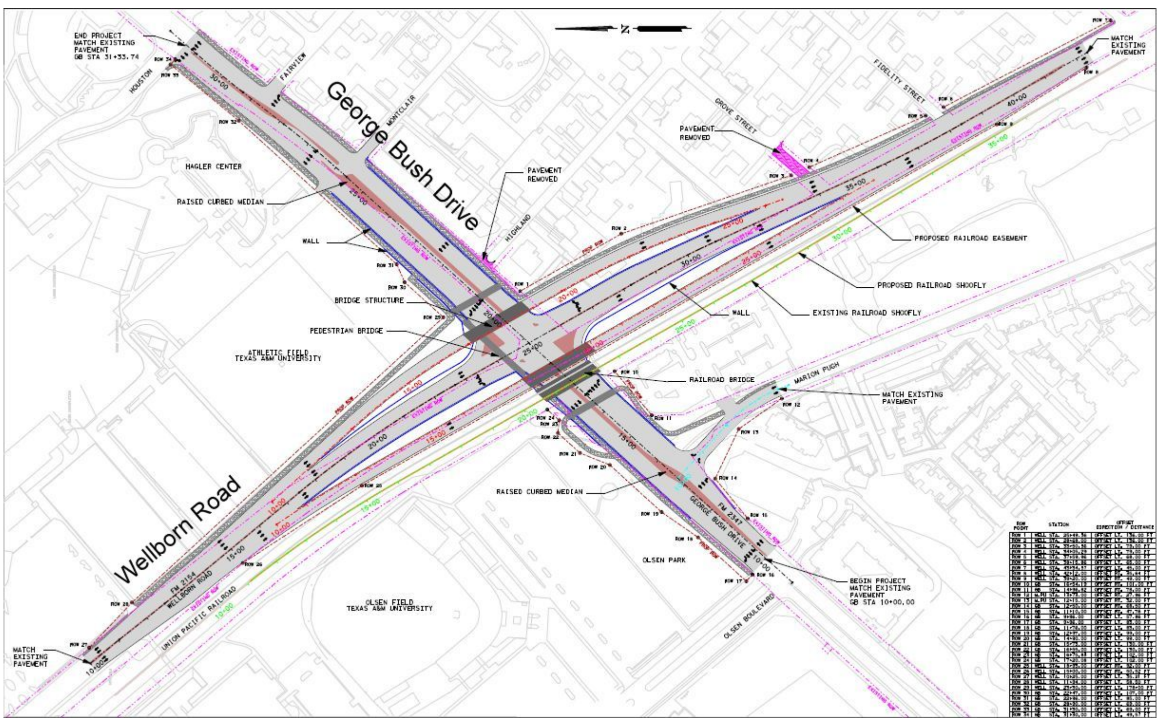


Figure 5.39 Map overview of proposed George Bush and Wellborn Road intersection

This intersection reconstruction project is a $25 million project in College Station, Texas to enhance mobility, pedestrian safety and reduce delays in the congested intersection in peak hours since Union Pacific Railroad (UPRR) and both roads, George Bush Drive and Wellborn Road (FM2154), with high traffic volumes share the same intersection.

The scope of this project includes:

- Excavation of existing grades to depress the mainlanes of the George Bush Drive and Wellborn road

- Construction of a rail road bridge over the depressed sections of the roadway while maintaining the existing tracks of UPRR

Challenges

The challenges involved with this project are discussed in detail by Jean Goyat (Goyat, 2012) a former researcher of the team, which primarily included heavy traffic, lack of construction space because of Texas A&M University facilities nearby and the construction schedule.

Two construction scenarios are proposed for construction of this intersection

Scenario 1 – This option tries to carry out the intersection construction with the maximum possible number of lanes open throughout construction. Phasing of construction is expected to be complex and also escalates cost of the project.

Scenario 2 – As per this scenario, the intersection is closed for all road users which will reduce the duration and cost of building the intersection.

The main objective of this case study is to use 3D/4D CAD models to present both scenarios to all stakeholders viz., Bryan and College Station city councils, TxDOT personnel, local public and Texas A&M University administration and convince them about the challenges involved with proposed scenario 1, thereby seeking approval for construction using scenario 2.

Use of 3D/4D CAD models for TMP

Earlier research by Goyat, 2012 showed the application of 3D/4D CAD models during the planning and design phase to visualize and understand the construction strategies in order to predict the impacts on traffic. Using these models, accurate representation of intersection construction scenarios were presented to stakeholders explaining the necessity of this project. Presentation of both construction scenarios to stakeholders simultaneously had a major impact on receiving public approval for the scenario to be applied during project execution. Scenario 1 had duration of 931 days while scenario 2 took only 421 days. The huge difference in duration for both scenarios is justified using 4D animations.

Also, different stages of construction were shown with vehicle 3D objects manually placed on lanes to add visual context and improve communication to the non-engineering audience. As a feedback, it was suggested that instead of 3D objects, real traffic conditions with 3-D models could help with better plan for intersection construction phasing. Moreover, the audiences were curious about the levels of congestion that motorists might face if construction is taken up with open lanes (scenario 1).

With traffic volumes received from TxDOT, the feasibility of adding traffic data to 3-D models was attempted by our team for the first time. Owing to the modeling and time constraints, only existing conditions were modeled in 3D. Constraints regarding modeling efforts, level of detail of model elements and implementation challenges were noted for future evolution of the integration process.

Use of 3D/4D models with traffic

Further to earlier research, traffic microsimulation models were developed for construction scenarios using TxDOT provided volumes in spreadsheets in contrast to the NTE model where traffic assignment models were used to extract volumes.

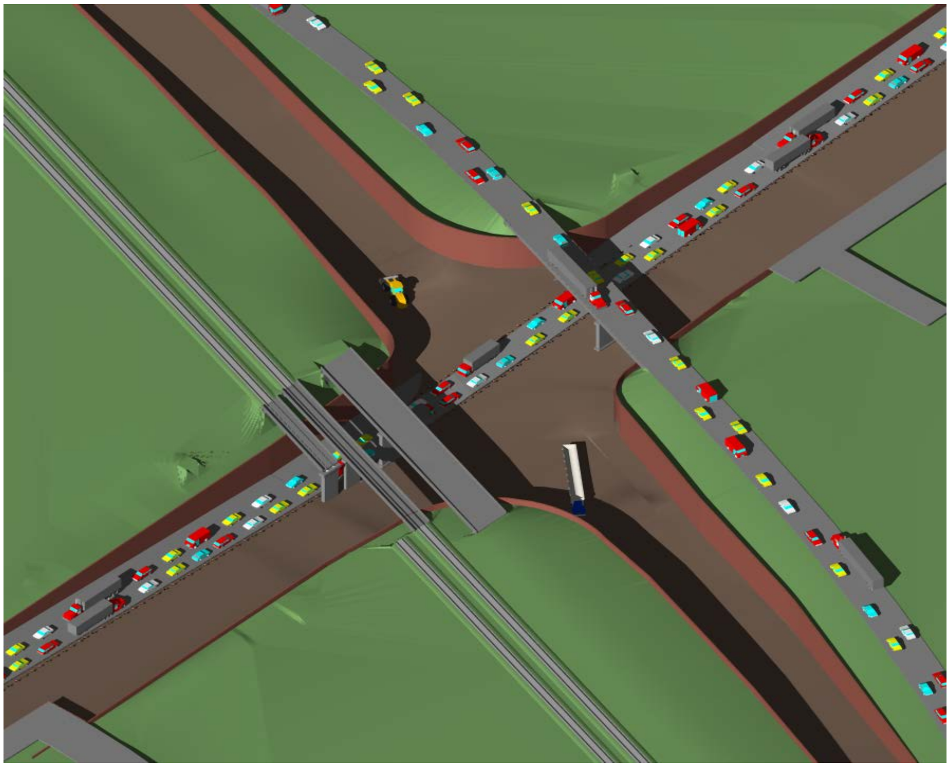


Figure 5.40 4-D model showing construction phasing with one lane open (Goyat, 2012)

Virtual reality

Use of real traffic data in visualization avoids miscommunication of predicted volumes during construction. It can be observed that in figure 5.41 George Bush Drive is so congested in the 3D model where vehicles are manually placed as 3D objects. However, when actual construction phase volumes are imported to 3D model from microsimulation models, congestion is observed to be less severe than in earlier visualizations. Road user traffic in work zones is generally added to provide the public with a sense of congestion expected as a result of the on-going construction. As the animationsfrom the models with traffic and construction are shared with the public through eAlerts in project websites, updated in social networking websites like Twitter and Facebook and local television media news, accuracy of visualization in construction and traffic is very crucial for the acceptance by the public.

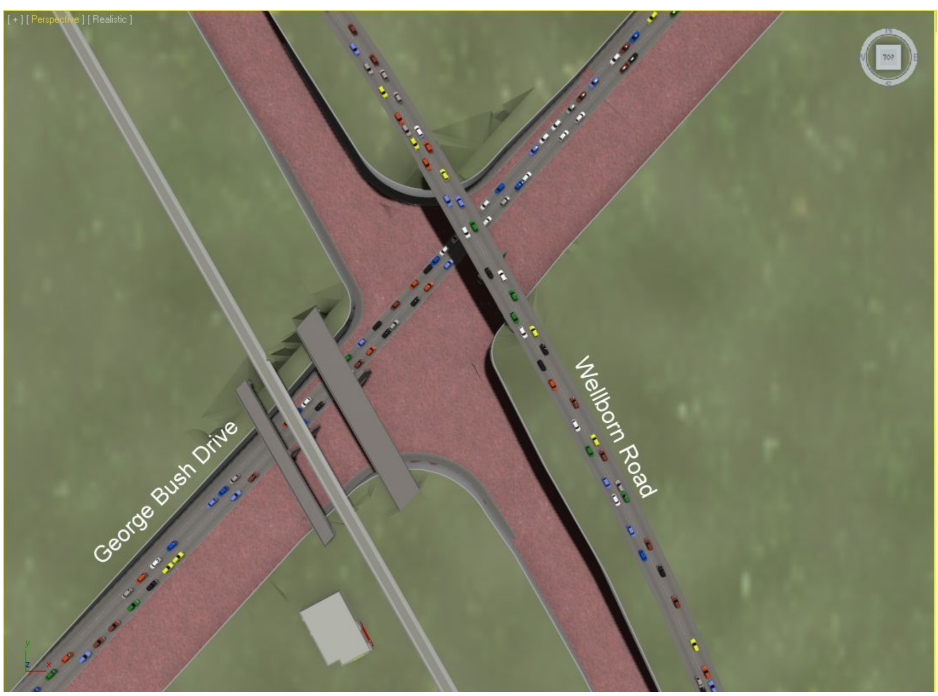


Figure 5.41 3D model with vehicle showing the expected traffic volume during this phase of construction

Virtual drive through

As mentioned in the literature review, DOTs and developers now-a-days use high end graphical representations of proposed projects during project planning phases to gain public approval and funding from various federal as well as public-private partnership agencies. However, most of the developers use non-engineering graphical rendering software for visualizing the proposed designs. Although those animations provide adequate representation of the project, more credibility can be added by using technically sound models like the ones with real time/forecasted traffic data. They can reflect the conditions (congestion, lane changes etc.,) that drivers will experience when driving through the project and add more reality to the virtual presentation. With capabilities like high computational power, engineering 3D models can also be applied rapidly as non-engineering graphic models. Also, wide availability of software like Autodesk Infrastructure Modeler® made creation of 3-D models relatively easy even without complete PS&E details which are generally developed during the detailed design phase of a project.

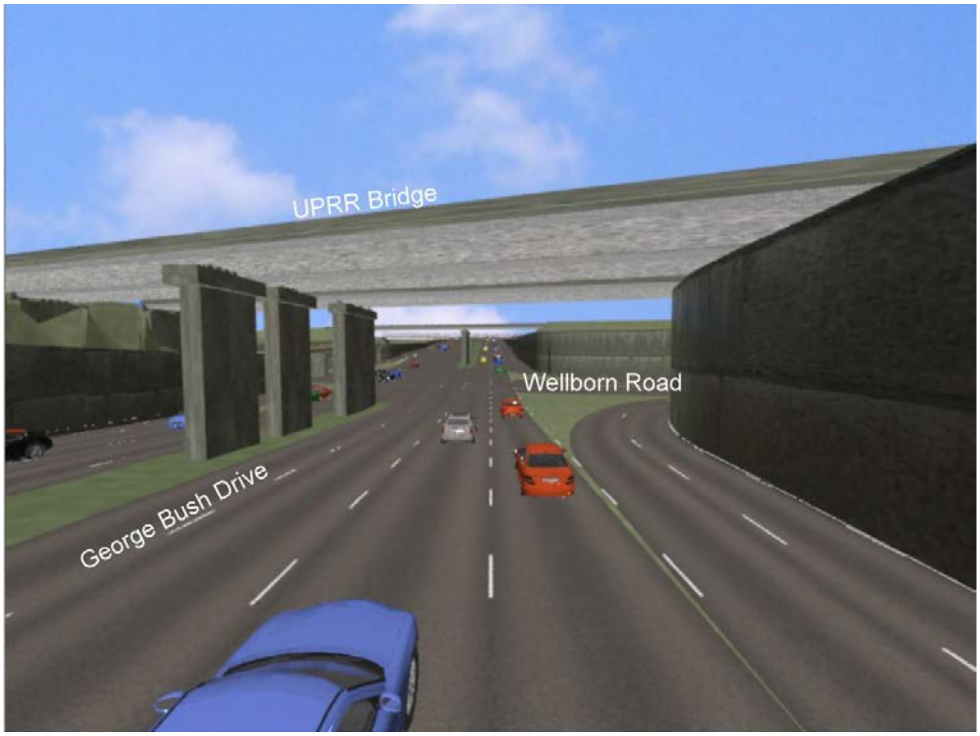


Figure 5.42 Virtual drive through showing planned future traffic conditions of the project after finish of construction

Observations

From this case study it can be said that the CAD models with traffic are the next frontier for visualization in roadway construction projects because of their ability to replicate the existing traffic conditions into CAD models. Additionally, the future traffic conditions can also be visualized for different scenarios like during construction and during regular operations after facility construction. This will be a very useful tool for traffic engineers and TMP planners to communicate their plans not only to non-engineers but also to developers and city agencies for review/approval.

JW MARRIOTT - AUSTIN DOWNTOWN

Collection of field traffic data for a project area of interest is time consuming and labor intensive process for any project team. In research methodology for this thesis, it was proposed that instead of collecting the field data separately using existing techniques (volume count/take-off from field/CCTV footage or loop counters), DTA models run by DOTs for regular operation can be used. However, DTA models are mesoscopic models which act as a transition between microscopic models and macroscopic models. Macroscopic models are characterized by density, volume and mean velocity of traffic flow in a large network whereas microscopic models analyze behavior of each vehicle and its interaction with surrounding environment like lane changes, yield, stops etc., (Rose, 2004) Mesoscopic models contain properties of both microscopic and macroscopic models. Hence, there is a necessity to calibrate the microscopic models or verify them with field data.

Overview

In order to validate the volumes and turning movements derived from mesoscopic DTA model, a construction detour scenario is chosen in nearby Austin downtown. Construction of 1,200,000 square-foot JW Marriott Austin hotel is being done on the northeast corner of Congress Avenue and 2nd St in downtown Austin, Texas (Hunt, 2012). Construction began in August 2012 and is expected to continue until the first quarter of 2015.

Figure 5.43 Rendering of proposed JW Marriott hotel in Austin downtown

Traffic control

TCP documents were not available to analyze the change in traffic volume due to construction. Hence, the construction site was visited and traffic control was analyzed using detours denoted by signage and traffic control devices placed around the construction site. During construction, westbound lanes on 2^{nd} street are narrowed from 3 to 1 between Congress and Brazos Street. Part of left turning traffic on Brazos Street to West 2^{nd} street is detoured on to West 3^{rd} street. Westbound lanes are closed between Brazos Street and Trinity Street. Left turning traffic from Trinity Street on to West 2^{nd} street is directed to West 3^{rd} street. Right turning traffic on south bound San Jacinto is detoured on to West 3^{rd} street prior to reaching 2^{nd} street.

Figure 5.44 Graphic denoting detours around JW Marriott hotel site

Validation

Traffic counts at intersections were collected to validate the volumes derived from the DTA model. Counts were done during peak hour of 5 pm to 6 pm at intersections 2nd Street-Congress Avenue and 3rd Street-Congress Avenue. Left turn, right turn and through movements were counted at both the intersections.

The turn volumes during construction were observed as tabulated below

Outflow at Intersection	Left turn	Through	Right turn	Total
2nd& Congress	45	24	closed	69
3rd& Congress	93	84	6	183

Table 5.1 Vehicle turn movement counts observed at 2nd and 3rd street intersections

In the microsimulation model with no construction scenario, the volumes are as follows

Inflow at Intersection	From Brazos left turn	From San Jacinto right turn	From Trinity left turn	Total
2^{nd}& Congress	86	135	1	222
3^{rd}& Congress	1	0	0	1

Table 5.2 Vehicle volumes for 2^{nd} and 3^{rd} street intersections in microsimulation model

Outflow at Intersection	Left turn	Through	Right turn	Total
2^{nd}& Congress	134	86	2	222
3^{rd}& Congress	1	0	0	1

Table 5.3 Vehicle turn movement volumes for 2^{nd} and 3^{rd} street intersections in microsimulation model

The microsimulation model is set up such that volumes for turn movements at every node are calculated based on the probabilities assigned for turn movements. It is assumed that the same proportion of vehicles take turns even during construction and the probabilities for turn movements is kept constant for the construction scenario. During construction, inflow volumes at the nodes of interest are changed due to closure of west 2^{nd} street and re-direction of traffic on to 3^{rd} street as follows

Inflow at Intersection	From Brazos left turn	From San Jacinto right turn	From Trinity left turn	Total
2^{nd}& Congress	86	0 (detour)	0 (detour)	86
3^{rd}& Congress	1	135	1	137

Table 5.4 Vehicle volumes for 2^{nd} and 3^{rd} street intersections in microsimulation model for construction scenario

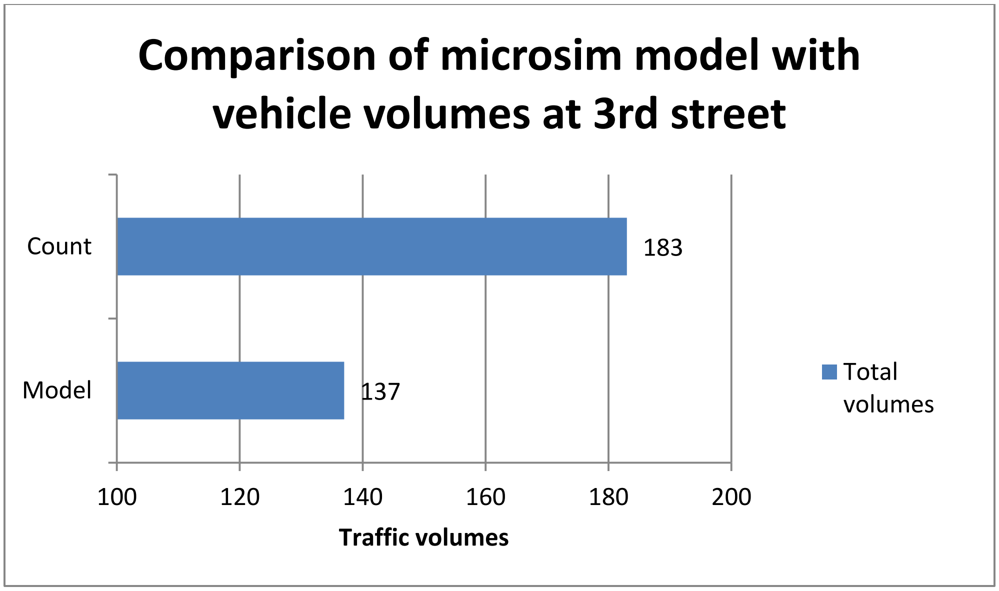


Figure 5.45 Bar chart comparing total volumes at 3rd street intersection from microsimulation model and field vehicle counts

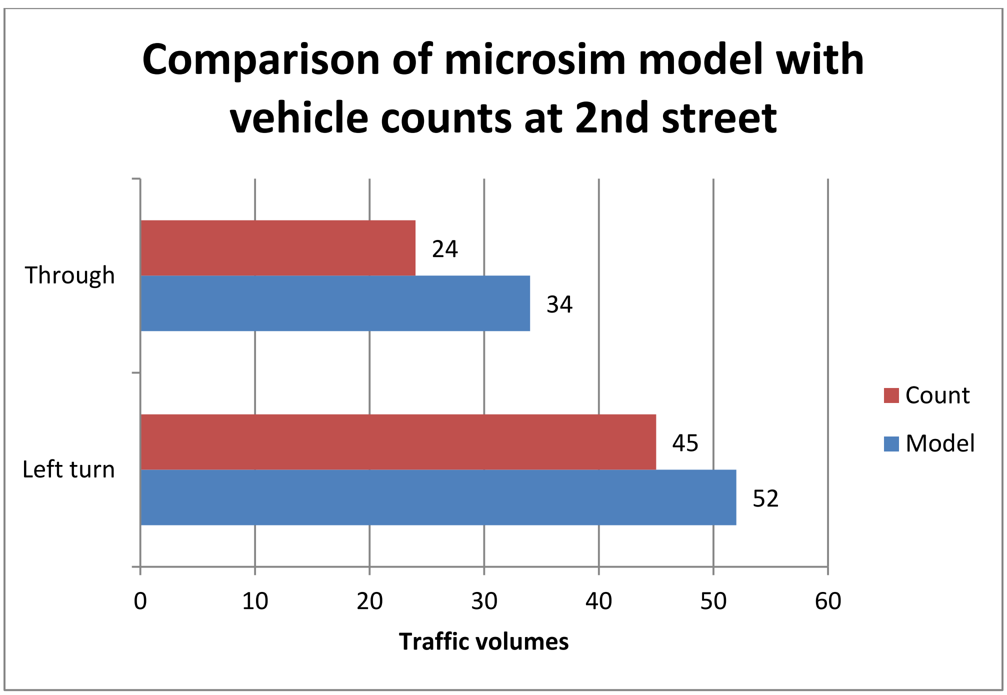


Figure 5.46 Bar chart comparing left and through movements at 2nd street intersection from microsimulation model and field vehicle counts

From the bar chart it is observed that the actual vehicle count at the intersection of 3rd street and Congress Avenue is 183 which is 33.57 % more than the expected volume of 137 vehicles. This anomaly can be attributed to the assumptions considered during the setup of the DTA model. When modeling the mesoscopic model, vehicle movements are directed towards sinks in the network. Sink can be a business location or a recreation place which is destination for many vehicles in a network. From the figure 5.48 it can be observed that sink is located on 2nd street. According to the model, the vehicles ending or originating in 3rd street at intersections with Brazos and San Jacinto come under the sink on 2nd street as they are connected to the sink (green lines). That is also the reason for volume for inflow at the intersection of 3rd street and Congress Avenue in the table 5.2 is 0. However in the real case scenario, 3rd street must have non-zero peak hour volumes. Also for Trinity Street, the location of the Austin Convention Center is considered as a sink in figure 5.48, hence turning volumes and through volumes are less than what they should be.

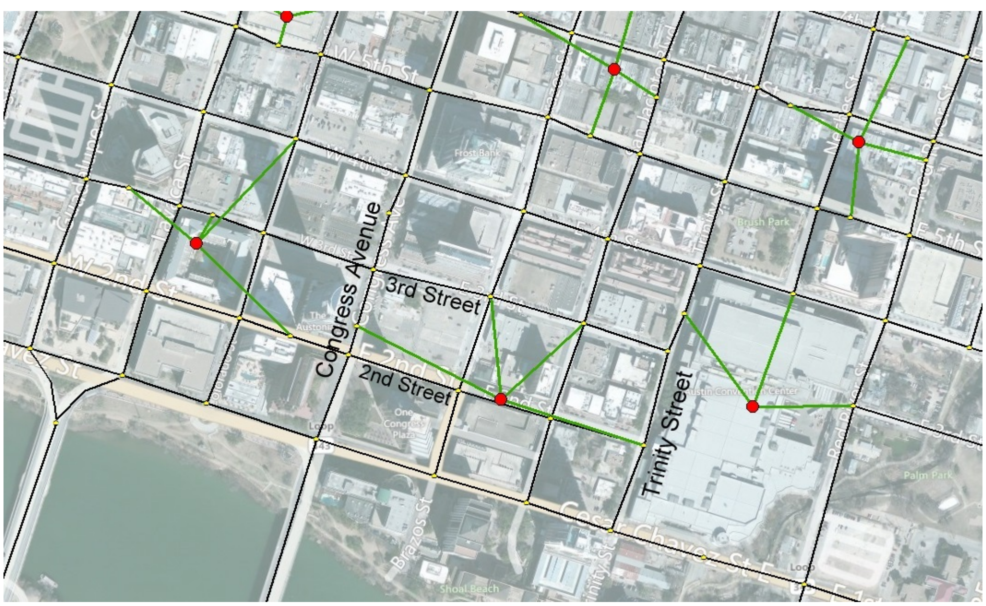


Figure 5.47 Image showing sink locations based on which vehicle volumes are derived

Also the turning volumes at intersection of 2nd street and Congress Avenue are slightly less than the predicted volumes in the microsimulation model as observed in figure 5.47. The reduction in volumes on west 2nd street is due to the general driver behavior to avoid construction zones. Since west 2nd street was narrowed down to 1 lane from 3 lanes and the area looks congested due to the placement of barricades, some drivers might have been prompted to use 3rd street instead of 2nd street.

From this analysis, it can be concluded that input data for microsimulation models from DTA models has to be further streamlined if construction in minor arterial roadways or city roads is considered. However, the traffic data generated for highway and major roadways is expected to be much accurate as the number of origin or destination points will be lower than city roads.

Chapter 6 Conclusions

BENEFITS

This thesis has proposed a new dimension to applications of 3D/4D CAD modeling in transportation construction projects. It is based on using mesoscopic DTA models run by DOTs to collect traffic information for the project area of interest and simulate real traffic conditions in microsimulation models. Output from microsimulation models is added to 3D/4D CAD models to further evaluate TCPs and communicate them better, rather than communicating the geometry and traffic conditions separately. To our knowledge, this is the first such modeling of using DTA models to represent traffic conditions in construction projects using CAD models based on our literature review.

The models turned out to be an efficient way to incorporate vehicular traffic conditions in addition to spatial and temporal conditions that CAD models have been addressing. Computational power and improved interoperability between software has facilitated to consider all parameters that can influence execution of infrastructure projects. These models are instrumental in communicating construction phasing, TCPs during each phase of construction, proposed geometric designs to convey complete information about the project. The final product is one virtual model, which can be used to communicate multiple aspects of the project as mentioned above. Models being incorporated with proposed geometry, TCP information and real-time traffic conditions, from which animations or pictures can be easily generated, they can be used by engineers (traffic engineers, TMP planners, builders) and non-engineers (local public, funding agencies, government bodies) for review of proposed plans. Change management process becomes consistent and easier as all the stakeholders can use a single model instead of multiple tools (3D geometry models, microsimulation animations). The same has been mentioned in the feedback collected by the author from transportation researchers and traffic engineers.

The thesis has laid down a framework for better planning, design analysis and communication of transportation projects across various stakeholders involved with the project. The methodology used to collect data is less time consuming than other traditional methods. However, the process of extracting regional traffic data from huge DTA models is still in evolving stage as the parameters considered for mesoscopic models and microscopic models are different. A concrete methodology is yet to be developed to bridge the gap between these two types of models to generate accurate data reflecting the real conditions. This is evident through the case study done in this thesis to validate the microscopic models generated using DTA models. Further refining is needed, when the localized details such as volumes of local streets are needed for analysis. Since DTA model generally allocates vehicle movement based on locations of sinks, the volumes might not reflect the actual conditions at micro level. Based on the results observed in case studies, this approach suits better for projects involving freeway and highway construction, as less number of sinks are encountered when compared to construction projects undertaken in urban or business areas.

As explained in the case studies, the prime focus of this report was directed towards traffic visualization during construction and TMP planning phases of a roadway construction project. Based on the observations and the feedback from surveys, the areas of challenge, the benefits achieved, their audience and relevance to that particular challenge area are tabulated as follows:

TMP Planning	Description	Benefits	Audience	Relevance
Communication	Communication of proposed traffic detour plans to stakeholders for approval and informing the motorists about the impact of construction on mobility	Use of real-time traffic data helped in educating motorists and public with an accurate view of geometry along with the traffic mobility conditions that can be expected during construction	Stakeholders – Builder/ Contractor, Public, Govt. agencies	High
Traffic control	Design of traffic control plans to minimize the impact on vehicle movements and maximizing the level of service on lanes carrying traffic during construction	The capability of visualizing traffic along with the construction road geometry allows for fast review and optimization of the devised TCP. In addition to 3D/4D model visualization, which only show changing geometry in a period of time, these models also review traffic performance during in the construction zone with time	TMP planners, City operation personnel	High
Workzone management	Moving traffic in work zones impose great influence on constructability and safety in work zones	Using a single model for traffic and geometry can also help in analyzing the work zone logistics , proximity of workers to traffic and barricade setup for safety	Safety officers, Superintendents, motorists and construction crew	Potential benefit – not analyzed

Table 6.1 Summary table for TMP planning phase

Construction	**Description**	**Benefits**	**Audience**	**Relevance**
Communication	Communication of construction phasing and the resultant traffic detours, closures, shifts between existing, temporary and proposed pavements	In NTE project case study, the benefits of visualizing traffic in each construction phase are extensively explained. The ability of models, to easily convey complex phasing information in a holistic approach, is invaluable for non-engineering audience	Stakeholders – Builder/ Contractor, Public, Govt. agencies	High
Traffic control	Complex phasing of roadway construction causes inconvenience to motorists, leading to safety hazards in work zones and greater delays than estimated	The drive through capabilities with driver's perspective and advanced renderings can provide motorists with information on driving conditions in construction zones in advance. These models can be used to inform public in a variety of ways. For example, animations can be generated and published to web in project websites or social media to educate as many people as possible through realistic visualizations	Motorists, public	High

Table 6.2 Summary table for Construction phase

Construction	Description	Benefits	Audience	Relevance
Workzone management	Traffic control devices form an integral part of workzone safety during construction with moving traffic	3D models with traffic data can be used to review the traffic control device plans for adequacy and effectiveness. They can be analyzed from driver's perspective and check if sufficient reaction time is offered by these devices for the drivers to react	Safety officers, TCP planners and motorists	Medium

Table 6.2 Summary table for Construction phase (cont.)

IMPLEMENTATION CHALLENGES

The benefits of these models are highly dependent on the accuracy of TCPs, schedules and the DTA models used to generate microsimulation models. Non-compliance of any of these can jeopardize the credibility of what these models communicate. Continuous review of these models by project schedulers, TMP planners and DOT operations is necessary for successful implementation of CAD models with traffic information.

With the software that is used in this thesis, it is difficult to develop a single 3D model with traffic data for huge construction project like North Tarrant Express, which is spread over a length of about 13 miles. The results of traffic microsimulation models are very much dependent on the surrounding conditions. Bigger the network, more are the parameters that affect simulation model's performance. Hence work zones for which these models have to be developed should be chosen only if the project team decides it is worthwhile to visualize traffic data with geometry. There are no parameters suggested in this thesis that can suggest which work zone area has to be selected. Public meetings and traffic planning/operations of DOTs are a good source to collect feedback on areas with complex TCP and congestion for any project. For example, N.Beach intersection case study was taken up based on interviews with public information officers of NTE project.

Any photorealistic representation of reality has to deal with the level of detail that has to be incorporated into the virtual creation. Past research suggests thatthe level of detail has to be ascertained based on the audience for the virtual models. During author's interviews with researchers and traffic engineers, feedback was sought for the same. Many of the traffic engineers felt the level of detail used in NTE case study is sufficient enough to communicate even to non-engineering audience as more details can confuse audience and the objectives of these models might get lost. However, some opined that inclusion of traffic control devices might add more reality to TCP communication as any construction zone is accompanied by traffic control devices to communicate to driving motorists.

RECOMMENDATIONS

Advanced computational power has made it possible to extract regional traffic data from DTA models and combine them with 3D/4D CAD models using microsimulation. More credibility can be added to these models with more contextual information around work zone area. This can be achieved by using point cloud technology and add existing infrastructure, landmarks etc. to improve communication as well as consider all the space constraints when designing for temporary pavements during TMP planning. Extraction of existing 3D models from point cloud data reduce time for modeling, thereby more efforts can be put for TCP analysis and review.

Further refinement can be done when generating input data for microsimulation models from DTA models. Area of interest (freeway, intersection, city streets) can be used to customize DTA models and extract data which can represent the reality up to the maximum extent. Most of the available software for modeling are customizable. Application Program Interface (API) can be used to introduce plug-ins into the application resulting in increased processing capabilities to combine 3D geometry information, traffic data etc. In this thesis, multiple 3D models are developed to represent each phase of construction and traffic information is added to each model. It would be very advantageous if different traffic data can be imported during different phases of construction in a 4D simulation using a single 3D model. That would tremendously decrease the modeling time and output can be delivered with less man hour efforts. Use of APIs in 4D simulators like Navisworks can make this possible.

Appendix

North Tarrant Express

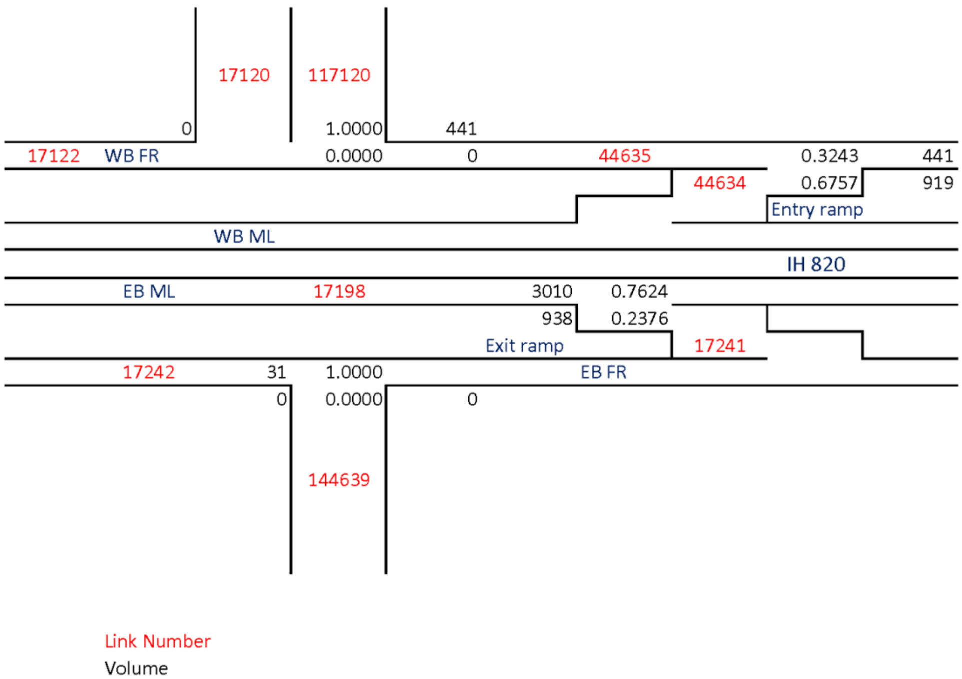
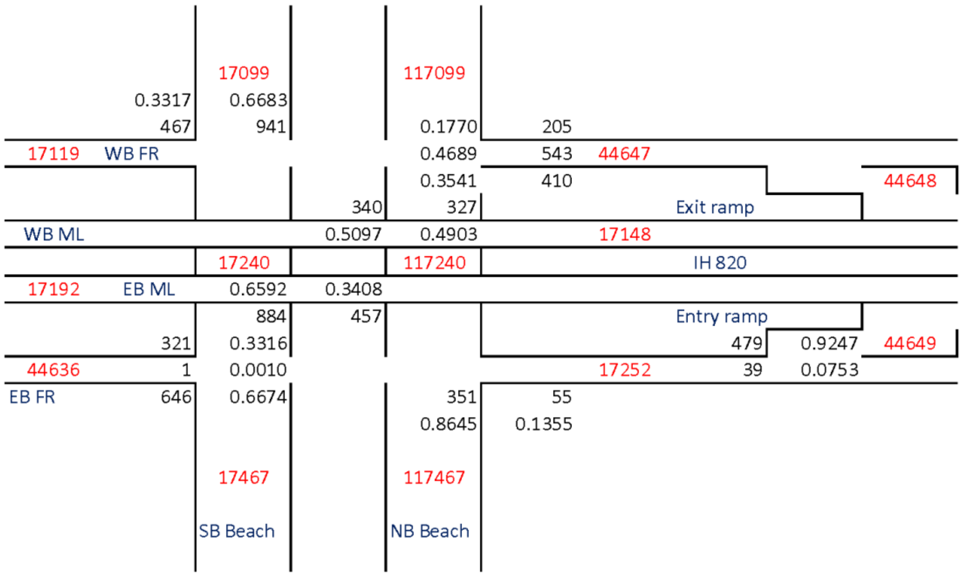


Figure 7.1 Traffic data for the NTE project



Link Number
Volume

Signal plan			
Phase	Dir	Prop	Time
2	EB	0.245685	37
8	NB	0.103046	15
6	WB	0.293909	44
4	SB	0.35736	54
Cycle Length		150	

Figure 7.2 Traffic data for the NTE project

FM 2154 AND GEORGE BUSH DRIVE INTERSECTION

Sept. 17, 2002

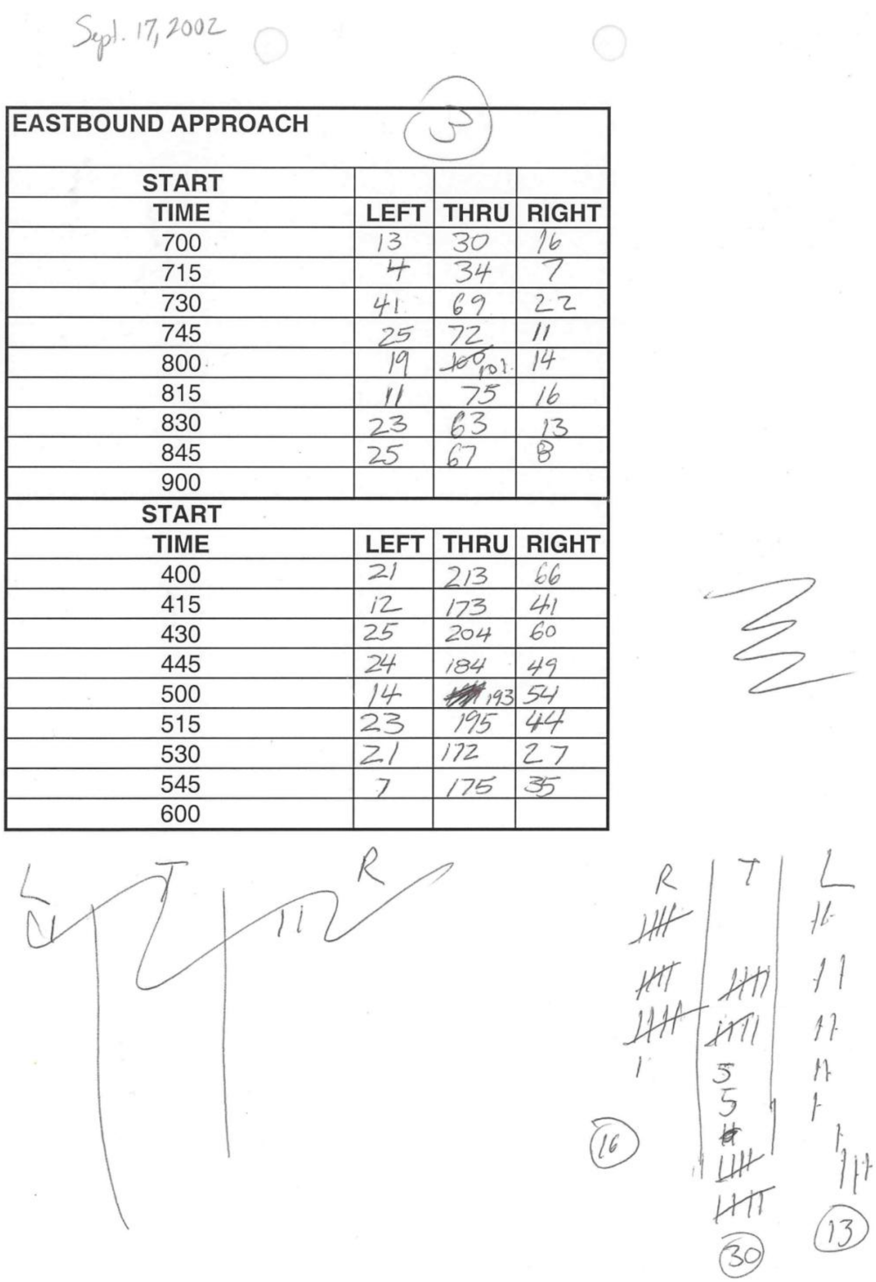
NORTHBOUND APPROACH			
START TIME	**LEFT**	**THRU**	**RIGHT**
700	45	88	43
715	39	76	37
730	136	205	79
745	79	178	76
800	97	201	86
815	73	146	70
830	69	105	67
845	123	147	68
900			
START TIME	**LEFT**	**THRU**	**RIGHT**
400	38	60	28
415	44	76	39
430	48	61	25
445	45	91	47
500	54	109	65
515	48	127	66
530	48	90	53
545	53	100	66
600			

TRAIN
TRAIN
TRAIN
TRAIN
TRAIN

1800 4 DEPT HELP

R T L

Figure 7.3 Traffic data for the FM 2154 project


Sept. 17, 2002

3

EASTBOUND APPROACH			
START TIME	LEFT	THRU	RIGHT
700	13	30	16
715	4	34	7
730	41	69	22
745	25	72	11
800	19	~~100~~ 101	14
815	11	75	16
830	23	63	13
845	25	67	8
900			
START TIME	LEFT	THRU	RIGHT
400	21	213	66
415	12	173	41
430	25	204	60
445	24	184	49
500	14	193	54
515	23	195	44
530	21	172	27
545	7	175	35
600			

L T R

R T L

5
5

16
30
13

Figure 7.4 Traffic data for the FM 2154 project

Sept. 17, 2002

SOUTHBOUND APPROACH	2		
START			
TIME	LEFT	THRU	RIGHT
700	11	36	11
715	5	27	3
730	20	34	9
745	20	44	20
800	27	48	33
815	19	42	28
830	22	28	4
845	28	52	18
900			
START			
TIME	LEFT	THRU	RIGHT
400	50	95	17
415	46	101	25
430	44	121	26
445	49	125	22
500	63	165	22
515	79	187	28
530	62	154	19
545	59	160	33
600			

Figure 7.5 Traffic data for the FM 2154 project

Sept. 17, 2002.

WESTBOUND APPROACH	(4)		
START TIME	LEFT	THRU	RIGHT
700	10	78	23
715	7	44	11
730	14	168	47.
745	4	94	55.
800 train	10	160	54
815 train	26	137	51
830 train	20	113	23
845	20	169	35
900			
START TIME	LEFT	THRU	RIGHT
400	41	116.	21
415 train.	44	147	28
430	43	121	31
445	54	154	37
500	69	148	61
515	62.	144	54
530 train.	67	165	39.
545	57	143	32.
600			

7:00 - 7:15.

Right	Thru	Left
23	78	10

7:15 - 7:30

Right	Thru	Left.
1		1

44:38

Figure 7.6 Traffic data for the FM 2154 project

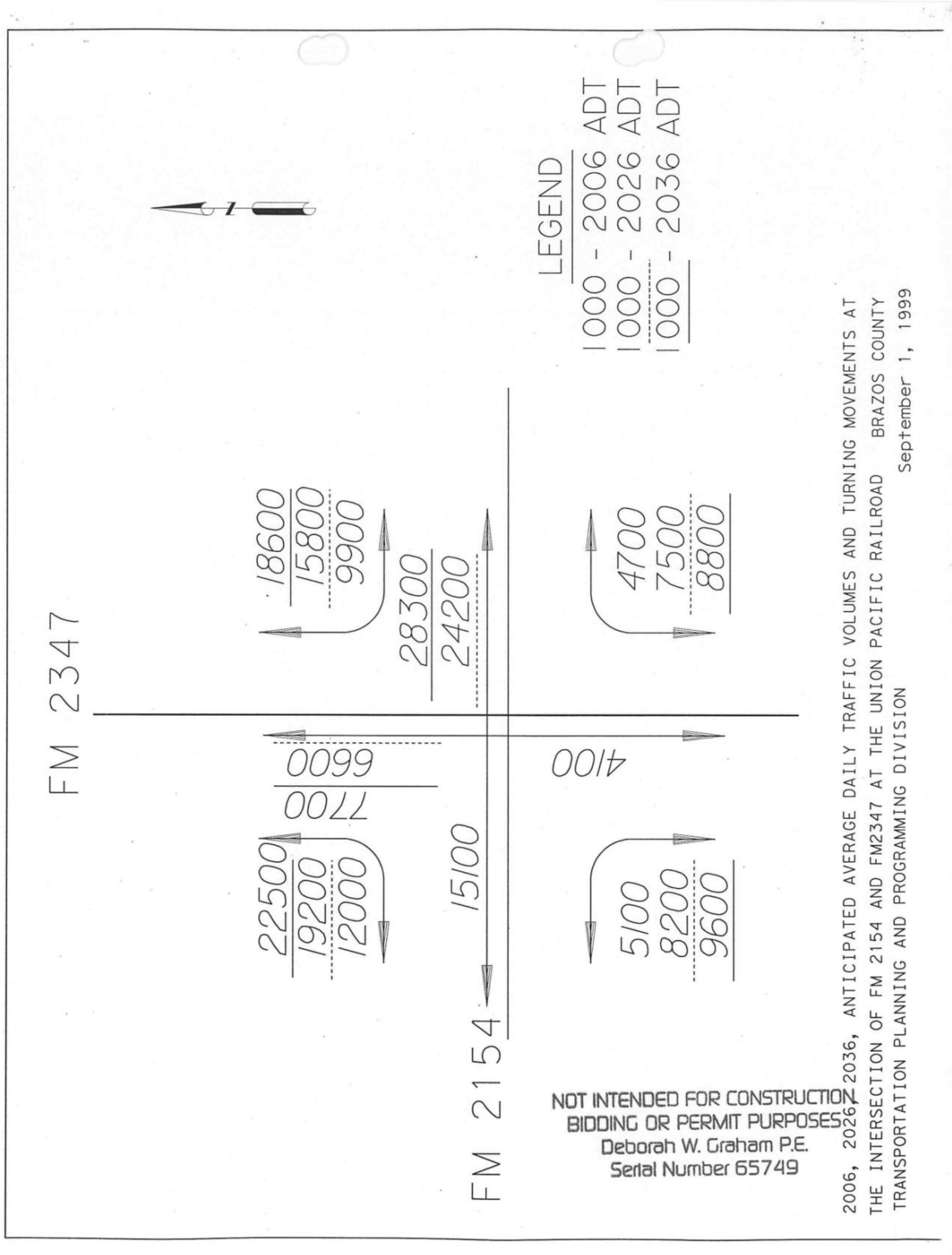


Figure 7.7 Average daily traffic volumes for FM 2154 project

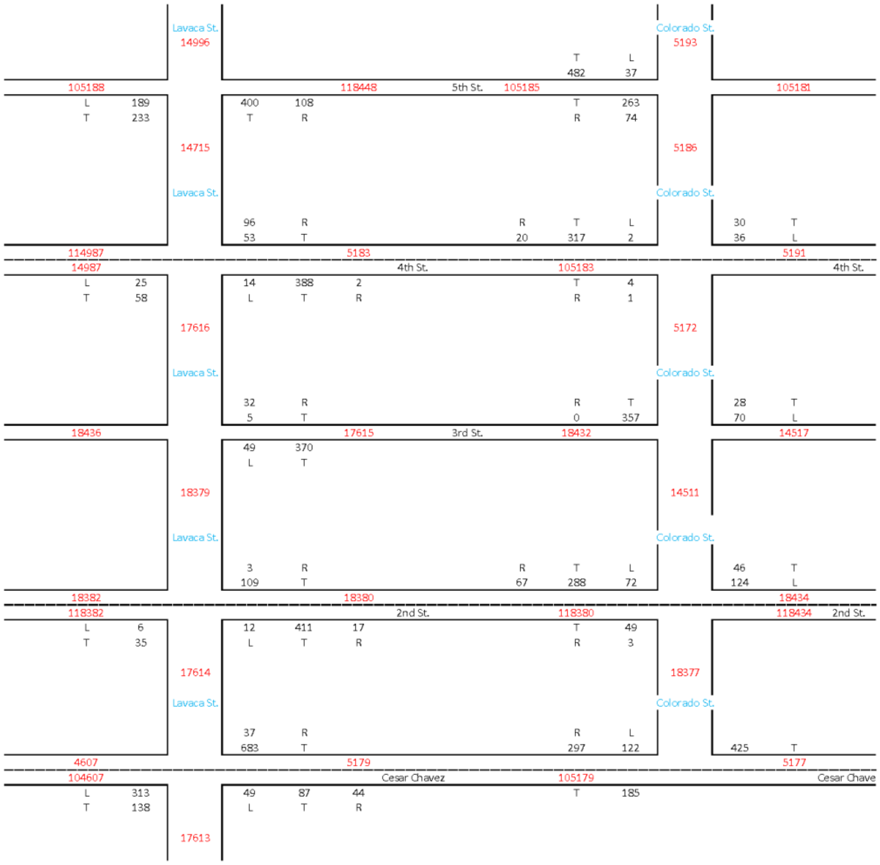


Figure 7.8 Traffic data for the JW Marriott project

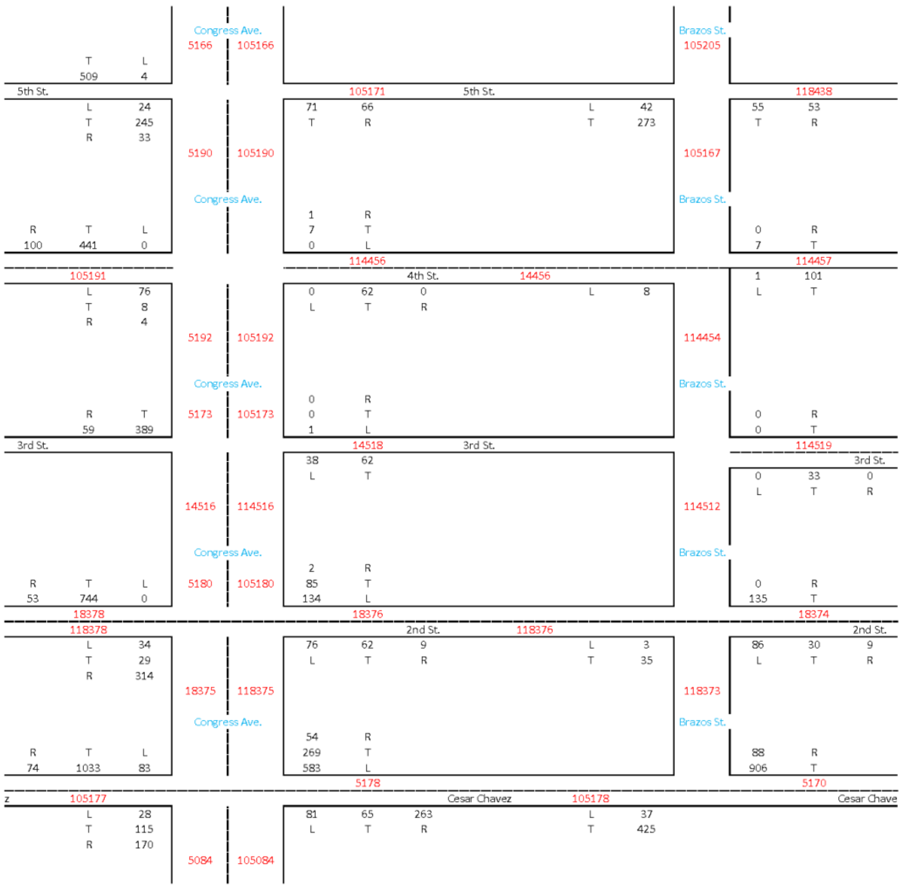


Figure 7.9 Traffic data for the JW Marriott project

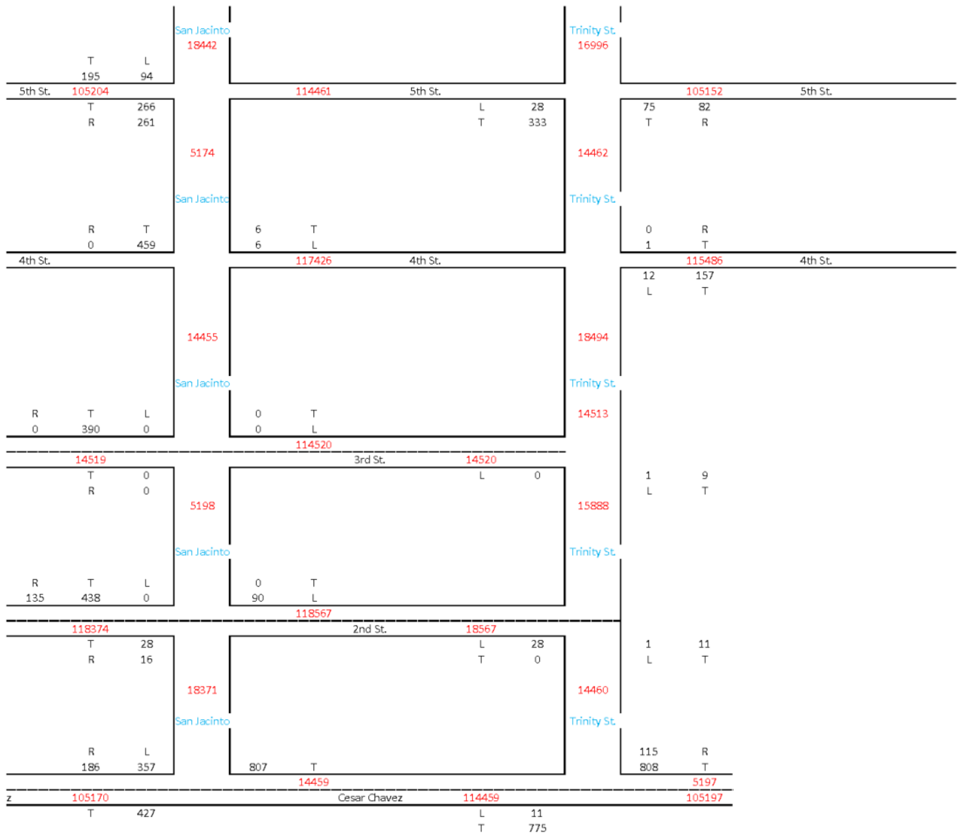


Figure 7.10 Traffic data for the JW Marriott project

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